KEITHLEY

Instruction Manual

Model 480
Digital Picoammeter

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INSTRUCTION MANUAL

MODEL 480

PICOAMMETER

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SECTION 1. INTRODUCTION.

1-1. GENERAL. The Model 480 is a 3-1/2 digit Picoammeter that provides 7 decade current ranges from 10^{-9} to 10^{-3} ampere, with 100% overranging on all ranges. The instrument features include an input voltage burden of $\leq$ 200μV, front panel zero check and adjustment, an analog output, and automatic polarity indication of the input current.

1-2. WARRANTY INFORMATION. The Warranty is given on the inside front cover of this Instruction Manual. If there is a need to exercise the Warranty, contact the Keithley Representative in your area to determine the proper action to be taken. Keithley maintains service facilities in the United Kingdom and West Germany, as well as in the United States. Check the inside front cover of the Instruction Manual for addresses.

1-3. CHANGE NOTICES. Improvements or changes to the instrument which occur after printing of the Instruction Manual will be explained on a Change Notice sheet attached to the inside back cover.

IMPORTANT

The ⚠ symbol can be found in various places in this Instruction Manual. Carefully read the associated CAUTION statements with regard to proper use and handling of the instrument. Damage to the instrument may occur if these precautions are ignored.

The ↯ symbol can be found in various places in this Instruction Manual. This symbol indicates those areas on the instrument which are potential shock hazards. Carefully read the associated WARNING statements with regard to proper use and handling of the instrument. Serious personal injury may result if these precautions are ignored.

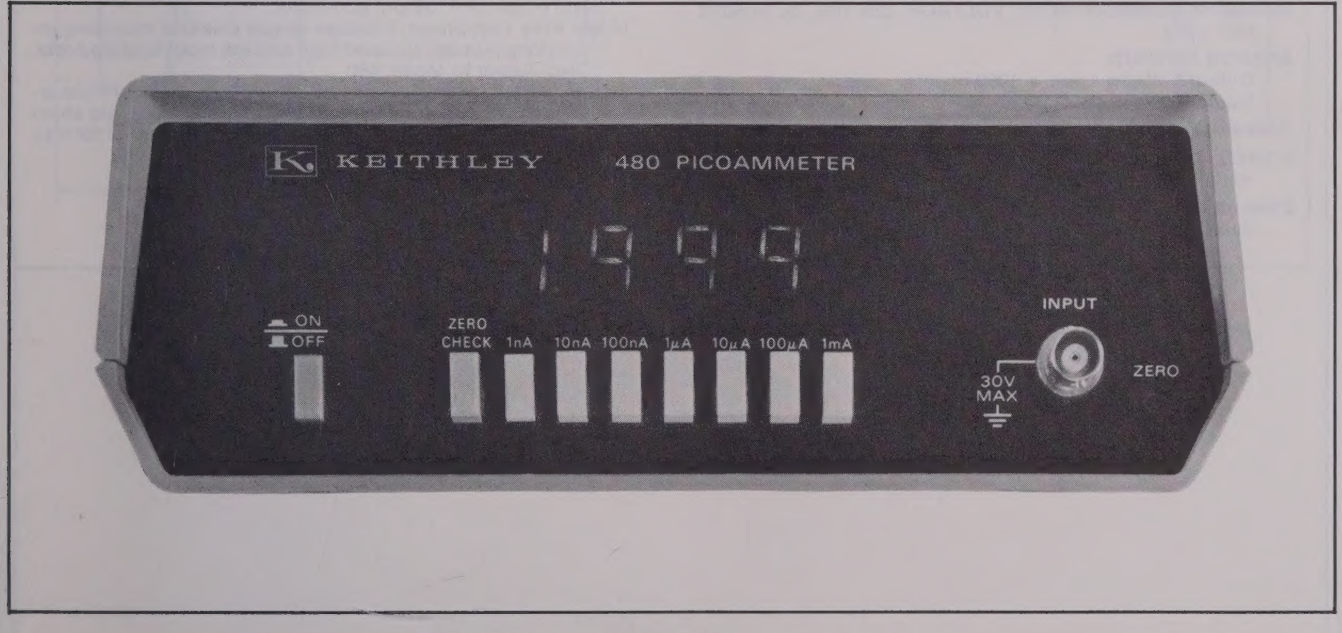


FIGURE 1-1. Model 480 Front Panel

SPECIFICATIONS, MODEL 480

RANGE	MAXIMUM READING	ACCURACY (12 MONTHS) 18°-28°C, UP TO 70% RH ± (% RDG + DIGITS)	ANALOG RISE TIME (10%-90%)	NORMAL MODE REJECTION RATIO (50 OR 60Hz)	MAXIMUM ALLOWABLE INPUT
1nA	1.999	0.8% + 4d	70ms	70dB	600V
10nA	19.99	0.8% + 3d	70ms	70dB	600V
100nA	199.9	0.5% + 3d	7ms	60dB	600V
1μA	1.999	0.5% + 3d	7ms	60dB	600V
10μA	19.99	0.5% + 3d	4ms	50dB	75V
100μA	199.9	0.5% + 3d	1ms	50dB	75V
1mA	1.999	0.5% + 3d	1ms	50dB	20V

MAXIMUM TRANSIENT OVERLOAD VOLTAGE: 1000V for 3 seconds from a Keithley supply limited to 10mA.

INPUT VOLTAGE BURDEN: Less than 200μV.

SETTLING TIME AT DISPLAY: Less than 1 second.

DISPLAY: Four 0.5" LED digits with appropriate decimal point and polarity indications.

CONVERSION PERIOD: 400 milliseconds.

OVERRANGE INDICATION: Display blinks all zeros above 1999 counts.

MAXIMUM COMMON MODE VOLTAGE: 30V rms, dc to 60Hz sine wave.

ANALOG OUTPUT:
Output Voltage: 1 volt = 1000 counts.
Output Resistance: 1000 ohms.

CONNECTORS: Input: BNC, Output: Banana Jacks.

POWER: 105-120 or 210-250 volts (switch selected), 50-60Hz, 6 watts nominal, 20VA max.

DIMENSIONS, WEIGHT: 85mm high x 235mm wide x 275mm deep. (3½ in. x 9¼ in. x 10¾ in.) Net weight: 1.7 kg (4 lbs.)

ACCESSORIES AVAILABLE:

Model 1788 Rechargeable Battery Pack: 6 hour minimum operation from full charge, recharges within 14 hours. Field installable. Adds 0.9 kg. (2 lbs.), 7 watts.

Model 4801 Input Cable: 4-ft. BNC to BNC low noise input cable.

Model 4803 Low Noise Cable Kit: Includes 50 ft. of low-noise coaxial cable, 10 BNC male connectors and 5 BNC female chassis-mount connectors .

Model 240A High Voltage Supply: ±0-1200 volt bias supply with ±1% accuracy, ±0.005% stability and 1 millivolt ripple and noise. UHF output connector.

Model 6104 Test Shield: Provides simple shielded mounting for checking leakage. Isolated high and low input binding posts, BNC output to Model 480 .

Model 6105 Resistivity Chamber: Guarded test fixture for measuring volume and surface resistivity of small non-rigid sheet samples 2 in. to 4 in. diameter. UHF input connector for bias supply, BNC output to Model 480

Model 1017 Dual Rack Mount Kit .

Model 1010 Rack Mount Kit .

Model 1684 Carrying Case .

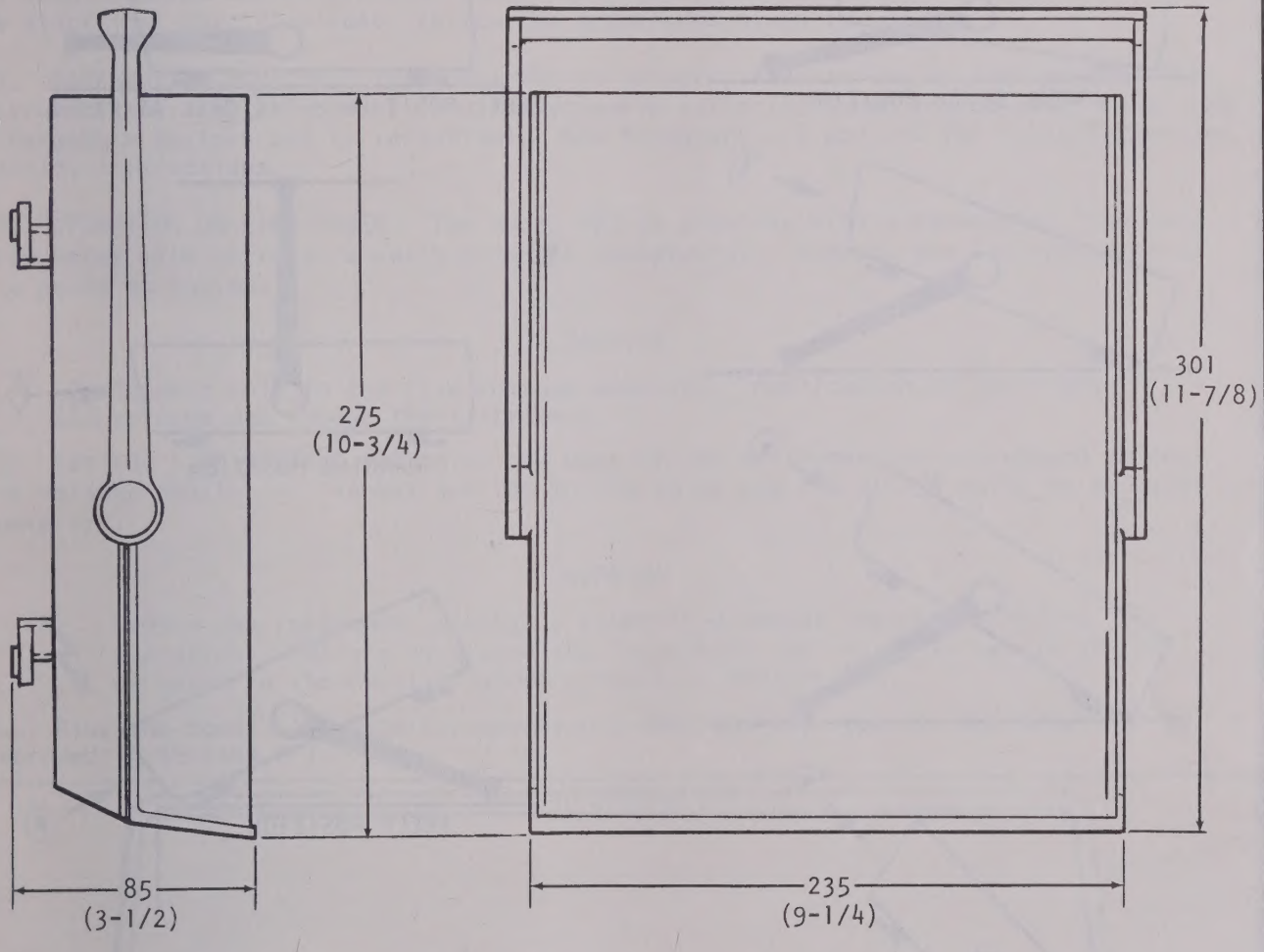


FIGURE 1-2. Dimensional Data

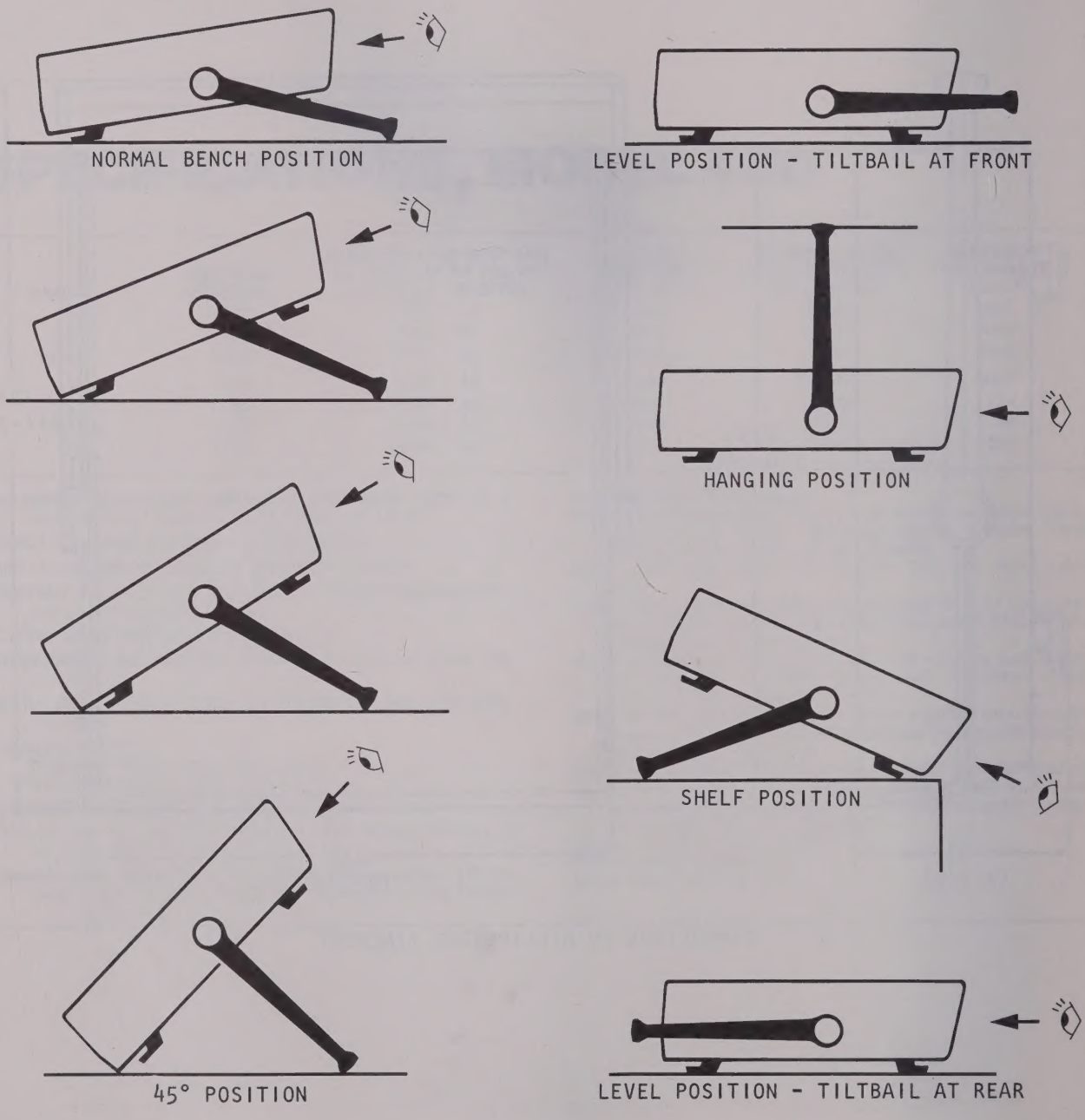


FIGURE 1-3. Tilt Bail Positions

SECTION 2. OPERATION.

2-1. GENERAL. This section provides information needed for operation, incoming inspection and preparation for use of the Model 480 Picoammeter.

2-2. INSPECTION. The Model 480 was carefully inspected both mechanically and electrically before shipment. Upon receiving the instrument, check for any obvious damage which may have occurred during transit. Report any damages to the shipping agent. To verify the electrical specifications, follow the procedures given in Section 3.

2-3. PREPARATION FOR USE. The Model 480 is shipped ready-to-use on line power. The instrument may also be powered from rechargeable batteries (when the optional Model 1788 Rechargeable Battery Set is installed). See Paragraph 2-5 and 2-6 for installation and charging instructions.

2-4. OPERATION ON LINE POWER. The Model 480 is provided with a three-wire line cord which mates with third-wire earth grounded receptacles. Connect the instrument to ac line power as follows:

CAUTION

⚠ Connect only to the line voltage selected. Application of incorrect voltage can damage the instrument.

a. Set the LINE VOLTAGE switch on the back of the instrument to correspond to the line voltage available. Ranges are 105 to 125 volts and 210 to 250 volts ac as shown in Figure 2-1.

WARNING

Ground the instrument through a properly grounded receptacle before operation. Failure to ground the instrument can result in severe injury or death in the event of short circuit or malfunction.

b. Plug the power cord into a properly grounded outlet. Operate the Model 480 as described in SECTION 2-7.

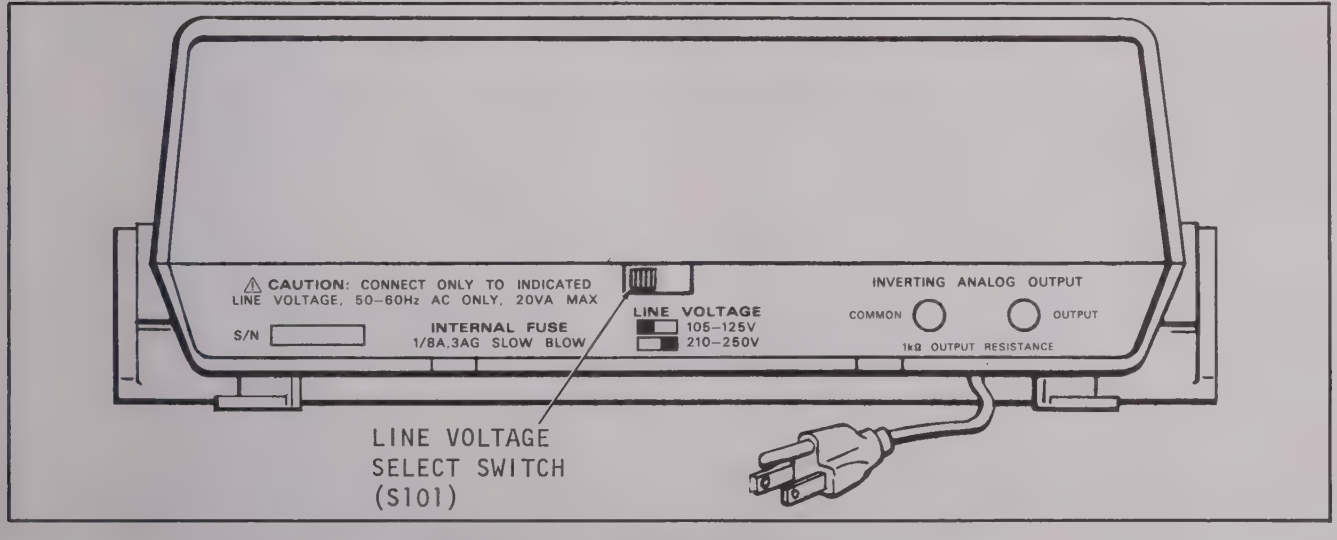


FIGURE 2-1. Model 480 Rear Panel

TABLE 2-1.
Summary of Range, Accuracy and Input Overload Information.

RANGE	MAXIMUM READING (NOTE 1)	ACCURACY ±(Reading + Digits) 18°C - 28°C	MINIMUM RECOMMENDED SOURCE RESISTANCE (NOTE 2)	OVERLOAD CONTINUOUS	
1nA	1.999nA	0.8% + 4d	100 MΩ	600V	TRANSIENT OVERLOAD 1000VDC FOR UP TO 3 SECONDS USING A KEITHLEY SUPPLY LIMITED TO 10mA OUTPUT CURRENT ~5 VOLT INTERNAL VOLTAGE CLAMP
10nA	19.99nA	0.8% + 3d	10 MΩ	600V	
100nA	199.9nA	0.3% + 3d	1 MΩ	600V	
1µA	1.999µA	0.3% + 3d	100KΩ	600V	
10µA	19.99µA	0.3% + 3d	10KΩ	75V	
100µA	199.9µA	0.3% + 3d	1KΩ	75V	
1mA	1.999mA	0.3% + 3d	100 Ω	20V	
		ZERO CHECK		50mA	

NOTES: 1. Current above maximum reading will result in a flashing 000 display.

2. Since source resistance is not always known, this recommendation can be restated in terms of minimum source voltage; i.e., current range x minimum source resistance = minimum source voltage. Thus, it can be seen that the recommended minimum source voltage for all current ranges is 100 millivolts.

NOTE

The Model 480 may be used with lower source resistance or voltage, with higher noise and measurement error, as described in Measurement Considerations, Paragraph 2-8.

2-5. OPERATION ON BATTERY PACK POWER. The Model 480 may also be operated from rechargeable sealed lead-acid batteries contained in the optional Model 1788 Battery Pack. The battery pack will operate the Model 480 for at least 6 hours from full charge. Circuits within the battery pack will automatically shut down the instrument when the battery charge is insufficient to maintain accurate readings. Refer to Figure 2-2 and install the battery pack as follows:

WARNING

Disconnect the line cord before removing the case cover.

a. Turn off the power and disconnect the line cord.

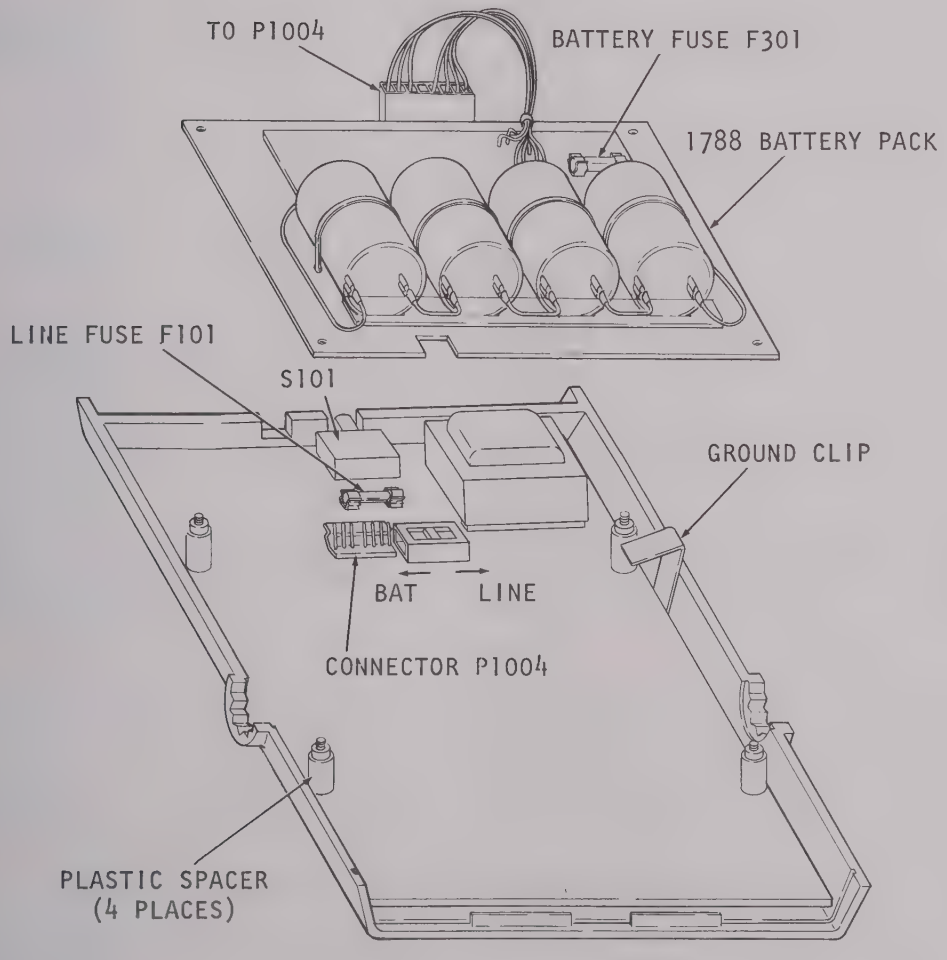


FIGURE 2-2. Battery Pack Installation

b. Turn the instrument over so that the bottom cover faces up. Loosen four slotted screws on the bottom cover. The screws are captive, that is they cannot be removed completely. Turn over the instrument with the top cover facing up, taking care to hold the top and bottom covers together. Carefully remove the top cover to gain access to the printed circuit board.

c. Set the BAT/LINE switch to the BAT position shown in Figure 2-2. Note that the battery pack will not operate properly if this switch is not in the BAT position.

d. Remove fuse F301 on the battery pack.

e. Install the battery pack in the instrument so that it rests on the plastic spacers. The ground clip must make contact with the upper side of the battery pack plate.

f. Carefully align the battery pack plug with connector P1004 on the circuit board. Push the plug firmly onto the connector until the lip on the plug engages the lip on the connector to lock the plug in place.

CAUTION

⚠ Make sure the connector is aligned so that all pins mate properly, otherwise, damage to the 480 will result.

g. Install fuse F301. Reinstall top cover and secure with four screws.

h. Charge the battery pack as described in Paragraph 2-6.

2-6. BATTERY CHARGING. The Model 1788 Battery Pack contains an integral battery charger. To charge or recharge the battery pack, install the battery pack in the Model 480 as described above and proceed as follows:

a. Connect the instrument to line power as described in Paragraph 2-4.

b. With the power switch off, the battery charge circuitry is automatically energized to charge the battery at the maximum rate. When the battery pack is first installed, or if it has completely discharged, allow it to charge for at least 14 hours in this condition

NOTE

For maximum battery life, do not allow the battery pack to remain completely discharged. Constant charging will not harm either the battery pack or the instrument.

c. When the Model 480 is in use on line power, the battery charger maintains a trickle charge on the battery pack.

2-7. OPERATING INSTRUCTIONS. Refer to Figure 2-3 and operate the 480 as follows:

a. Turn on the power by depressing the ON/OFF pushbutton.

b. Select the current range by depressing the appropriate pushbutton.

c. To check/adjust Zero, proceed as follows:

1. Have INPUT connected to source of less than 200μA or to an open circuit. Do not short INPUT as this condition would cause the instrument to overrange.

2. Depress the ZERO CHECK pushbutton. Momentary or locking action can be achieved depending on how far the button is depressed. To adjust zero, push button in to the lock position.

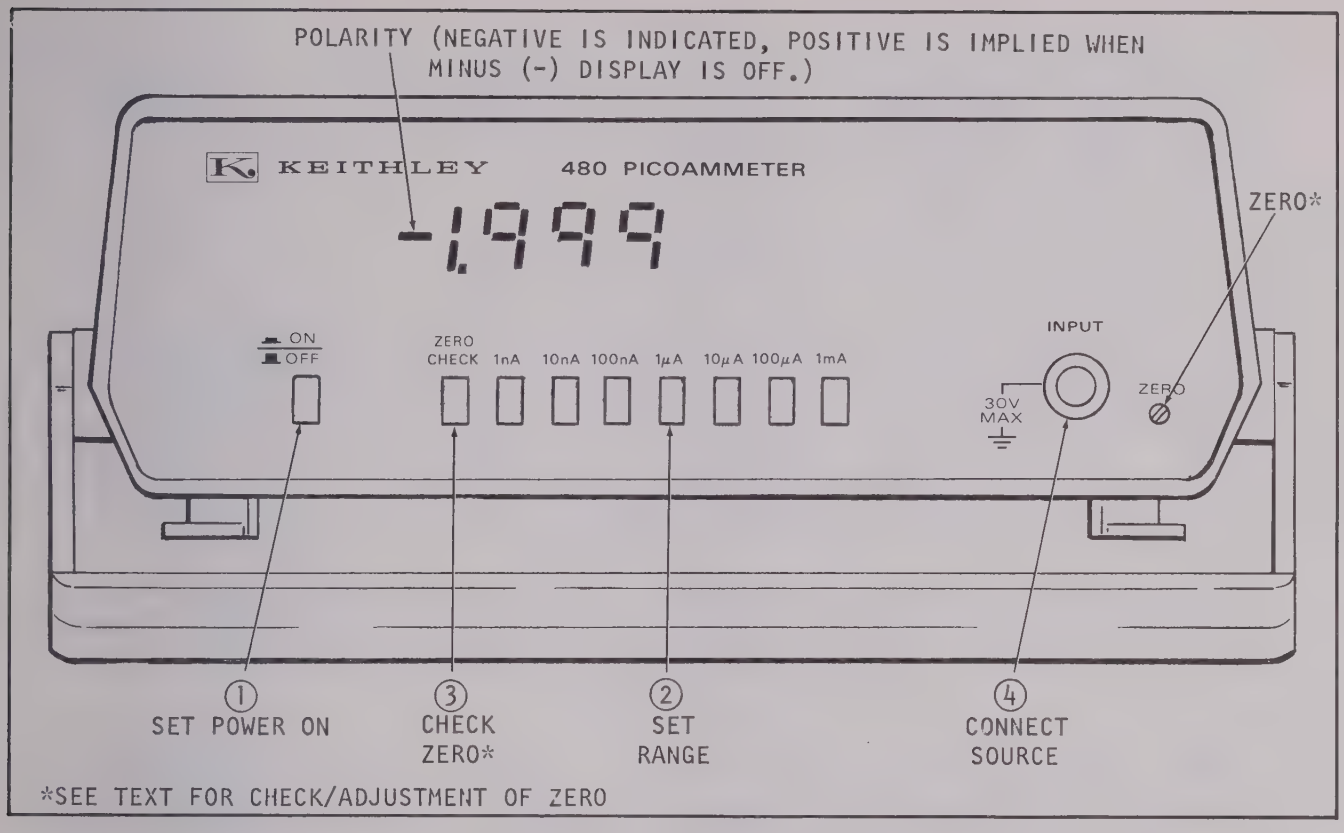


FIGURE 2-3. Operating Controls

3. Adjust zero level trimpot via access hole on front panel for a zero indication on the digital display, if desired.

NOTE

When zero is properly adjusted, the input voltage burden for an on-range reading will be less than or equal to 200μV.

CAUTION

⚠ During power up and power down, using AC line or battery pack, a current surge (≈25mA, 5V maximum) can appear at the INPUT of the Model 480. Protect any circuitry that would be damaged by these levels by making circuit connections only after turning on the Model 480. Disconnect these circuits before turning off the Model 480.

d. Connect the source to the INPUT connector on the front panel. Low-noise cable and connector accessories described in Section 4 should be used as required. Measurement considerations are discussed in Paragraph 2-8. A summary of range, accuracy and input overload information is given in Table 2-1.

CAUTION

⚠ Do not exceed the maximum input overload ratings. Instrument damage may occur.

e. Read the input current on the digital display, overrange is indicated by a flashing 000 display.

NOTE

On the 1mA current range an input overload exceeding approximately 10 volts could result in an on scale reading, rather than the flashing "000" indication. This will not damage the instrument, providing that the specified 20 volts is not exceeded, but will result in an erroneous display.

f. Inverting Analog Output. Two banana jacks (shown in Figure 2-1) are rear panel accessible, and permit monitoring or recording of the output from the current-to-voltage converter within the Model 480. Since the 480 is a feedback picoammeter, as shown in Figure 2-4, the input current is forced through the feedback resistor and an inverted analog output voltage is developed by the operational amplifier. The feedback (Range) resistors are selected such that voltage for an on-scale reading on any range will be between zero and ± 2 volts. The relationship between the analog output signal and the digital display is 1000 digits = 1 volt, or 1mV/digit except during zero check when it is 100μV/digit. The analog output is input protected up to 20V rms and during a input current overload is clamped to a maximum voltage swing of approximately ±5 volts. Although protected up to 20 volts to prevent instrument damage, a voltage applied to the Analog Output greater than 10 volts could cause an erroneous display, rather than the flashing 000.

Since the output of the current-to-voltage converter is bipolar, the Analog Inverting Output can also be used to measure low frequency ac currents which fall within the specified analog rise times. The Inverting Analog Output resistance is 1KΩ.

2-8. MEASUREMENT CONSIDERATIONS. This section describes the effects of source resistance, capacitance, noise and leakage resistance on the measurement. Minimum and maximum values of these source parameters are defined, at which point a significant degradation of the measurement can begin to occur, and compensation methods are described to minimize these effects. Refer to Figure 2-5 for the following discussion.

a. Source Resistance. As listed in Table 2-1, a minimum value of source resistance is recommended for each current range because E_{OS} is multiplied by $\frac{R_{FB} + R_S}{R_S}$ and because the input burden (<200μV) becomes important as E_S gets smaller.

For Example: On 1nA Range where: E_S = 10mV,
R_S = 10MΩ
R_{FB} = 100MΩ

$$\frac{R_{FB} + R_S}{R_S} = 11$$

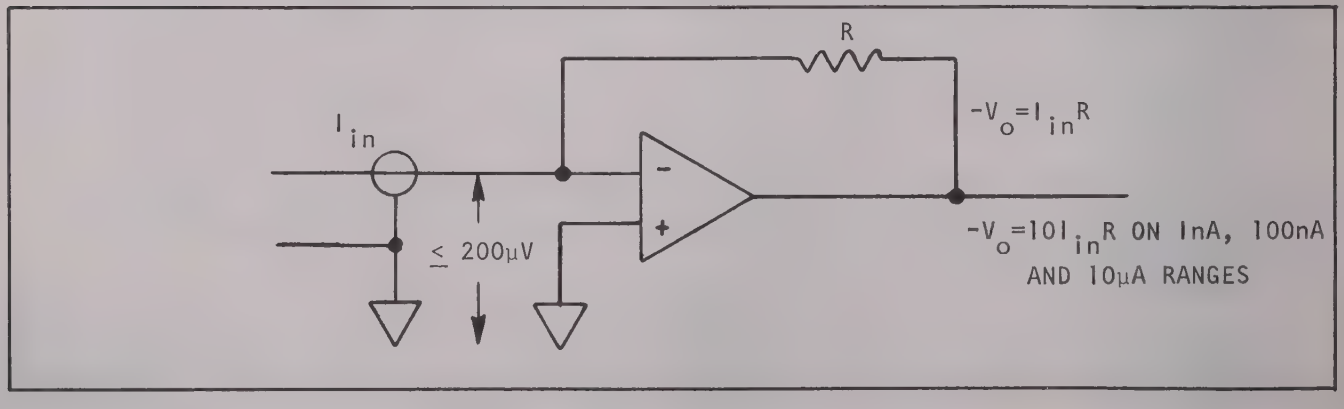


FIGURE 2-4. Model 480 Feedback Picoammeter.

The zero error would now be 11 digits, assuming zero check to 1 digit. If E_S can be shorted, this error can be compensated for by readjusting zero without actuating the ZERO CHECK pushbutton. An alternate method would be to disconnect the source and connect a resistor equivalent to R_S across the input of the Model 480. Zero could then be readjusted without depressing the ZERO CHECK pushbutton, as described above. There would still be an error due to the effect of the burden on E_S. This error is determined by:

$$\text{SPAN ERROR} = \frac{200\mu V}{10mV} = 2\%$$

This error would shift the operating characteristics of the circuit being measured by approximately 2%. Replacing the values above with the minimum recommended values for the 1nA range (100MΩ and 100mV), it can be seen that the SPAN ERROR would be reduced to 0.2%, which would result in the displayed current being within the specified accuracy for the 1nA range. In addition, E_{NOISE} is also multiplied by $\frac{Z_F + Z_S}{Z_S}$.

However, $E_{NOISE} << E_{OS}$ and is not significant until C_S becomes large.

b. Source Capacitance. The instrument is designed to accommodate up to 10,000 pF input capacitance. Increasing input capacitance beyond this level will increase noise and induce instrument instability.

$$\text{NOISE OUT} = E_{NOISE} \frac{(Z_F + Z_S)}{Z_S}$$

WHERE: $Z_S = R_S // C_S$ and $Z_F = R_F // C_F$

With a large value of C_S, Z_S could become less than Z_F at low frequencies. Combined with the 1/f (f = Frequency) distribution of JFET input noise, this could result in excessive noise on the Inverting Analog Output and on the display. Beyond this point, increased input capacitance could cause instrument instability. However, the instrument can be used with large input capacitances by adding additional capacitances (C_{EXT}) across C_F. This can be accomplished by connecting a capacitor from the Inverting Analog Output to the

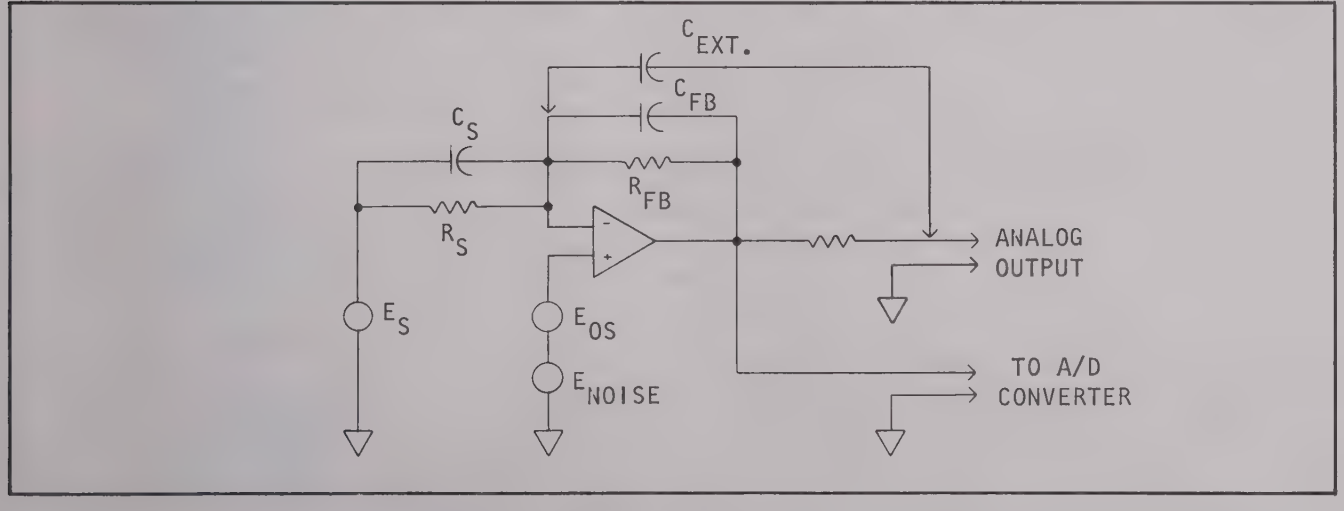


FIGURE 2-5. Measurement Considerations

Input. In order for the 1kΩ output resistor (R118) to have little effect on this compensation, it should only be performed on the bottom four current ranges (1nA - 1μA). In addition, the capacitors used should have an extremely low dielectric leakage characteristic (i.e., Polystyrene or Polyethylene). The addition of external feedback capacitance will have the direct effect of slowing instrument response time.

Example: 1nA range WHERE: C_{EXT} = 1000pF
R_{FB} = 100MΩ
C_{FB} = 220pF

$$\tau = [R_{FB} (C_{FB} + 10\ C_{EX})]^{-1}$$

↑ due to x10 Feedback divider.

$$\tau = (1E8 \times 10{,}220\ E\text{-}12)^{-1}$$

$$\approx 1 \text{ second}$$

This will result in a 10-90% response time of approximately 2.2 seconds. When adding external feedback capacitance, the noise performance will be improved by a level that is dependent on the characteristic of input impedance. Reduction of noise levels can best be accomplished by experimenting with increasing values of C_{EXT} until an adequate noise versus response time compromise is obtained.

c. Leakage Resistance. The effect of leakage currents should be considered when making small current measurements with high impedance sources. Leakage current and its effects can be minimized by using high resistance insulation in the test circuits and guarding. Since the Model 480 is a feedback picoammeter, it is effectively guarded at the input (≤200μV). The effect of leakage paths on the measurement can be further minimized by using a guarded test fixture as shown in Figure 2-6. In the configuration shown, the current through the component under test will not be shunted significantly be either leakage resistance path. If a high voltage supply without internal current limiting is used to make high resistance leakage measurements, it is suggested that a series current limiting resistor be used to prevent exceeding the maximum overload input limit of the Model 480 in the event the item under test is shorted. If the optional Model 240A High Voltage Supply is used, current will be limited to 10mA and the series resistor will not be necessary to protect the Model 480, unless the transient overload time or subsequent continuous overload limits are exceeded. If a custom test fixture is not required, the optional Model 6104 Test Shield or Model 6105 Resistivity Chamber may be useful in your application. These accessories are described in Section 4, and both have provisions for guarding.

d. Operation Outside of Specified Temperature Humidity Range. Typical 480 performance outside the operating range of 18°C to 28°C (but within, 0°C to 50°C and up to 70% relative humidity) will be ±(0.02% +0.5d) /°C for the 1nA, 100nA and 10μA ranges and ±(0.02% + 0.05d) /°C on all other ranges. Above 70% relative humidity the instrument accuracy can be expected to decrease significantly. However, no permanent accuracy impairment will occur unless a condensing condition is encountered.

e. Zero Time Stability. The typical zero time stability of the Model 480 is less than 1 digit drift per week, exclusive of temperature effects.

f. Floating Operation. The Model 480 can be operated with up to 30 Vrms (dc to 60Hz sine wave) of common mode (floating) voltage without degradation of specified performance. However, care must be taken to shield the circuit being measured to prevent noise pickup.

g. Storage Temperature Limits. Do not store the Model 480 outside of the temperature range of -25°C to +55°C.

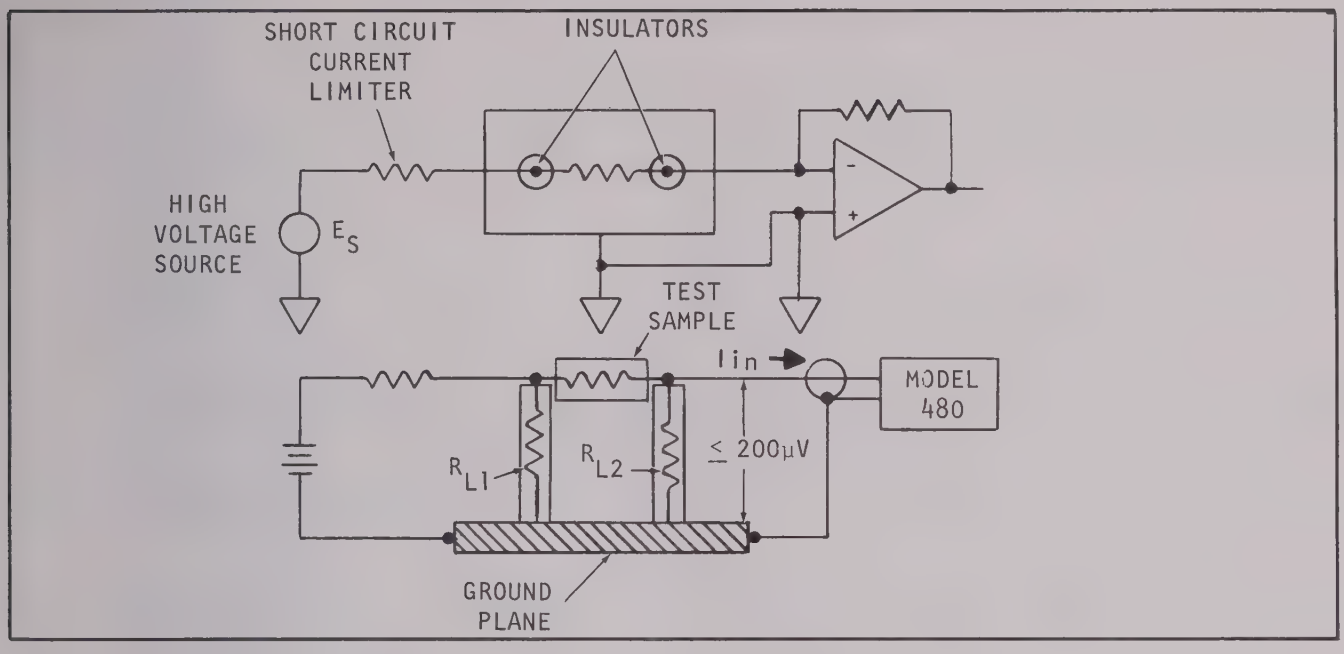


FIGURE 2-6. Test Fixture Guarding

SECTION 3. PERFORMANCE VERIFICATION.

3-1. GENERAL. Performance verification may be performed upon receipt of the instrument to ensure that no damage or misadjustment has occurred during transit. Verification may also be performed whenever there is question of the instrument's accuracy and following calibration, if desired.

NOTE

For instruments that are still under warranty (less than 12 months since date of shipment), if the instrument's performance is not within specifications at any point, contact your Keithley representative or the factory immediately.

3-2. RECOMMENDED TEST EQUIPMENT. Recommended test equipment for performance verification is listed in Table 3-1. Alternate test equipment may be used. However, if the accuracy of the alternate test equipment is not at least 10 times better than the instrument specifications or equal to the specifications in Table 3-1, additional allowance must be made in the reading obtained.

3-3. ENVIRONMENTAL CONDITIONS. All measurements should be made at an ambient temperature within the range of 18° to 28°C (65° to 82°F), and a relative humidity of less than 70%.

3-4. PERFORMANCE VERIFICATION PROCEDURE. Use the following procedures to verify the basic accuracy of the Model 480 for current measurements. If the instrument is out of specifications at any point, perform a complete calibration as described in Section 6, unless the instrument is still under warranty, as noted above.

NOTE

Performance verification should be performed by qualified personnel using accurate and reliable test equipment.

a. Initial Conditions. Before beginning the verification procedure the instrument must meet the following conditions:

1. If the instrument has been subjected to extremes of temperature, allow the internal temperatures to stabilize for one hour minimum at the environmental conditions specified in Paragraph 3-3.

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death.

b. Battery Pack Removal. If the Model 1788 Battery Pack is installed in the instrument it must be removed to gain access to internal adjustments and test points.

WARNING

Disconnect the line cord before removing the case cover.

1. Turn off the power and disconnect the line cord. Remove the four screws from the bottom of the case, and separate the top cover from the bottom cover.

TABLE 3-1.
Recommended Test Equipment for Performance Verification.

ITEM	DESCRIPTION	SPECIFICATION	MFR.	MODEL
A	DC Calibrator	0.190000V, 1.900000V, 19.000000V, 190.0000V, to within 20 ppm or 20μV	Fluke	343A
B	Multimeter, Digital	1.0000 ±0.0008V, within 0.013% of reading.	K-I	172
C	Oscilloscope		TEK	T935
D	Step Function Generator	2V, 20V Square Wave 0-50 Hz	Wavetek	110
E	Frequency Counter	100 kHz, within 0.01%	Fluke	1900A
F	Precision Shielded Resistors	10KΩ ± 175 ppm, 10MΩ ± 300 ppm, 100MΩ ± 2000 ppm, @ 25°C ± 3°C.	-	-

2. Push back the gound clip (shown in Figure 2-2) from the upper side of the battery pack, and remove the battery pack from the spacers. Disconnect the Battery Pack connector.

NOTE

For test point locations see Figure 6-1. The measurements should be made between the test points and power supply common (Ground Clip shown in Figure 2-2). For convenience, the INVERTING ANALOG OUTPUT-COMMON may also be used.

c. Normal Mode Rejection Ratio (NMRR) Test. NMRR is dependent on the clock frequency. Check the clock frequency as follows:

1. Set up the frequency counter (E) for a input signal of 0-5 volt @ 100kHz.

2. Connect the frequency counter to TP3 and check clock frequency for 100kHz ±90 Hz.

d. Range Accuracy Check. To properly check the accuracy of the Model 480 current ranges, precision current sources are necessary. These precise currents are obtained by using the DC Calibrator (A) and shielded series resistors. It is suggested that the resistors be arranged in a shielded test fixture, as shown in Figure 3-1, which will facilitate making the checkout without having to change connections. This fixture can also be used during the Rise Time check.

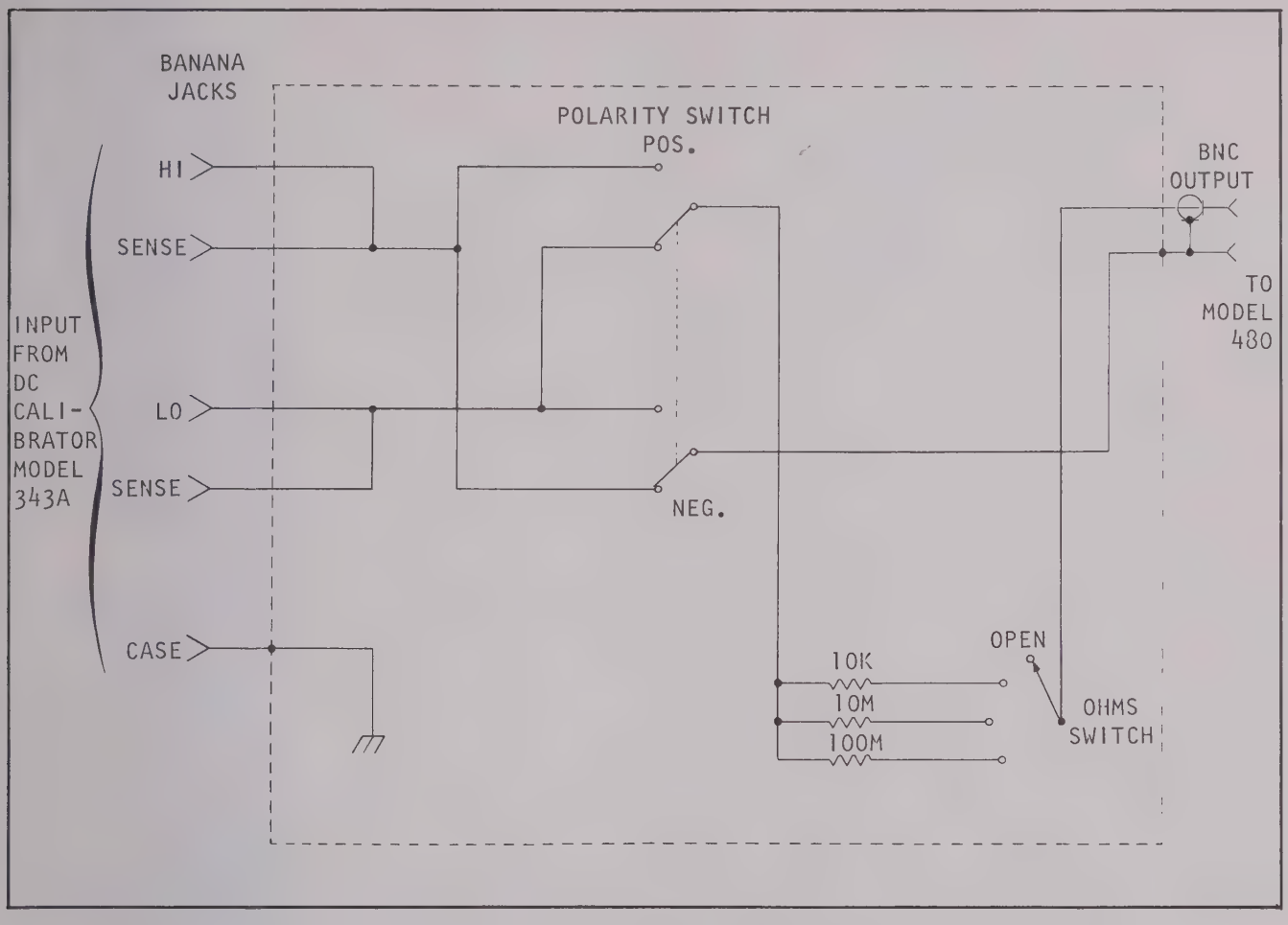


FIGURE 3-1. Shielded Test Fixture - Range Accuracy Set up.

1. With power off, connect the 343A DC Calibrator and the Model 480 to the test fixture.

2. Turn the Model 480 on, and perform the checks in Table 3-2 by setting 480, 343A, and test fixture to the specified settings. Note: The 343A output must be floating.

3. Turn the Model 343A off and disconnect it from the fixture.

e. Rise Time Check. See Figure 3-2 for test set up.

1. Connect Model 110 Function Generator SYNC OUTPUT to EXTERNAL TRIGGER INPUT of Oscilloscope.

2. Connect Model 480 INVERTING ANALOG OUTPUT to VERTICAL INPUT of oscilloscope.

3. Connect Model 110 OUTPUT to test fixture INPUT.

4. Connect oscilloscope case to test fixture case. Set test fixture to POS. position.

TABLE 3-2.
Range Accuracy Check.

343A SETTING	TEST FIXTURE SETTING	480 SETTING	480 DISPLAY
1.900000V	Open	1mA zero check (adjust if required)	.000
		1nA	.000±1 digit
		10nA	0.00
		100nA	00.0
		1µA	.000
		10µA	0.00
		100µA	00.0
		1mA	.000
19.000000V	10KΩ Pos	1mA	1.900±12d
	Neg		-1.900±12d
1.900000V	10KΩ Neg	100µA	-190.0±12d
190.0000V	10MΩ Neg	10µA	-19.00±12d
19.00000	10MΩ Pos	1µA	1.900±12d
1.900000	10MΩ Pos	100nA	190.0±12d
.190000	100MΩ Pos	1nA	1.900±15d*
	Neg		-1.900±15d*

* The possible 0.2% error of the 100MΩ resistor has been subtracted.

5. Set Model 110 to SQUARE WAVE OUTPUT, 50 Hz.

6. Set oscilloscope to .5V/div., DC Coupled, EXTERNAL TRIGGER, -SLOPE, TRIGGER LEVEL as required.

7. Perform the checks in Table 3-3 by setting Model 480, oscilloscope, Model 110 and test fixture to the conditions specified. Adjust Model 110 amplitude for 2V peak-to-peak analog output from Model 480. Check 10% to 90% rise time and verify response is free of ringing. A typical response on the 10nA range is shown in Figure 3-3. Figure 3-3 also shows the 10nA range with the oscilloscope time compressed to 20mS/div. to verify the absence of ringing and overshoot.

f. Post Test Setup. After satisfactory completion of the rise time tests in Table 3-3, return the Model 480 to normal operating condition as follows:

1. Remove power from the Model 480 and test instruments.

2. Disconnect the Model 480 from line power and the test equipment.

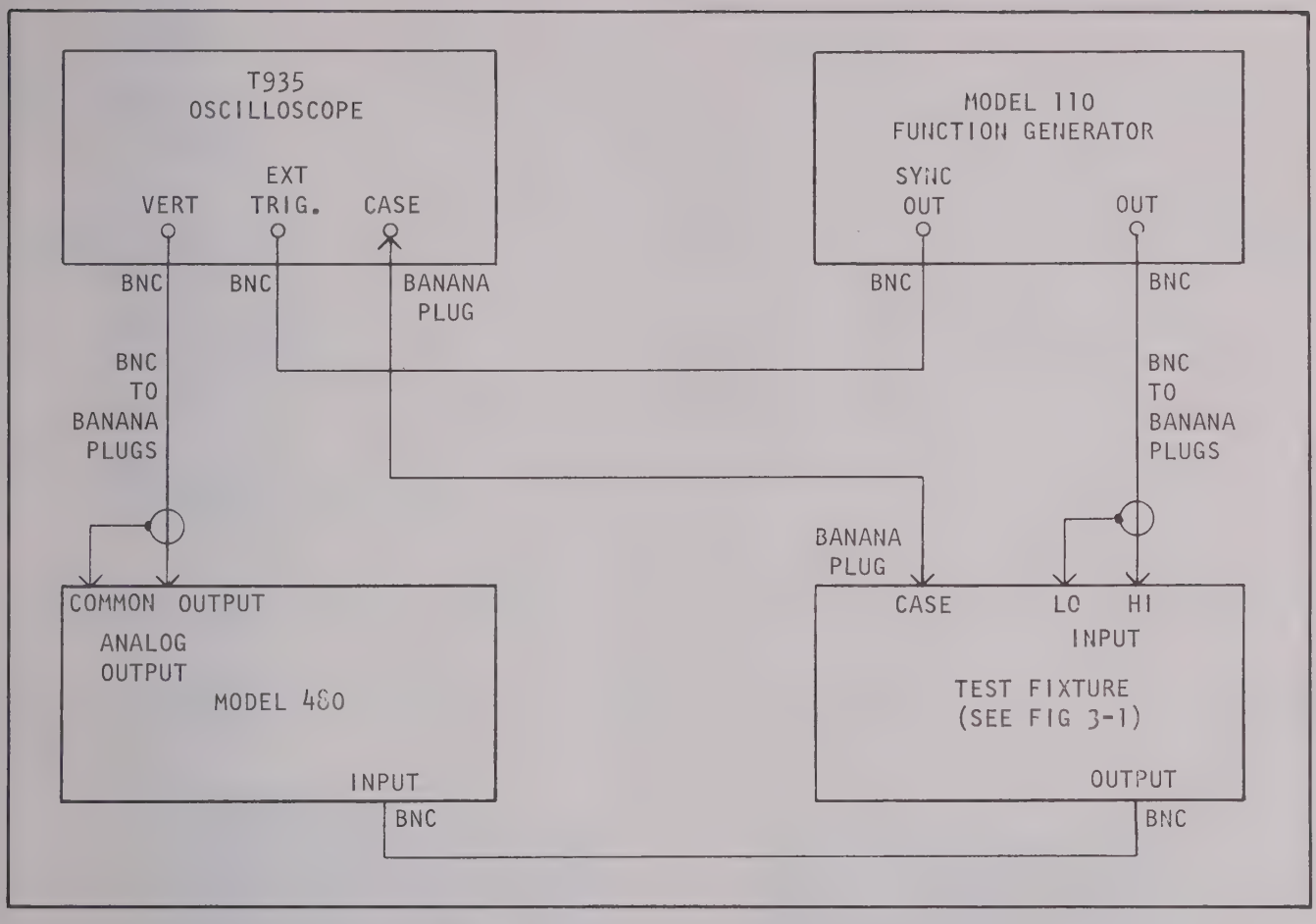


FIGURE 3-2. Rise Time Set Checks

TABLE 3-3.
Rise Time Tests

480 RANGE	TEST FIXTURE SETTING	MODEL 110 FREQUENCY	SCOPE TIME	RISE TIME 10% to 90%
1mA	10K	50Hz	.2ms/div.	.5ms to 1.0ms
100μA	10K	50Hz	.2ms/div.	.5ms to 1.0ms
10μA	10K	5Hz	1ms/div.	2ms to 4.0ms
100nA	10M	5Hz	1ms/div.	3.5ms to 7.0ms
10nA	100M	2Hz	10ms/div.	35ms to 70ms

3. If applicable, install Model 1788 Battery Pack in accordance with the instructions in Section 2.

4. Reinstall the top cover by reversing step b-1. above.

5. Operate the Model 480 as described in Section 2.

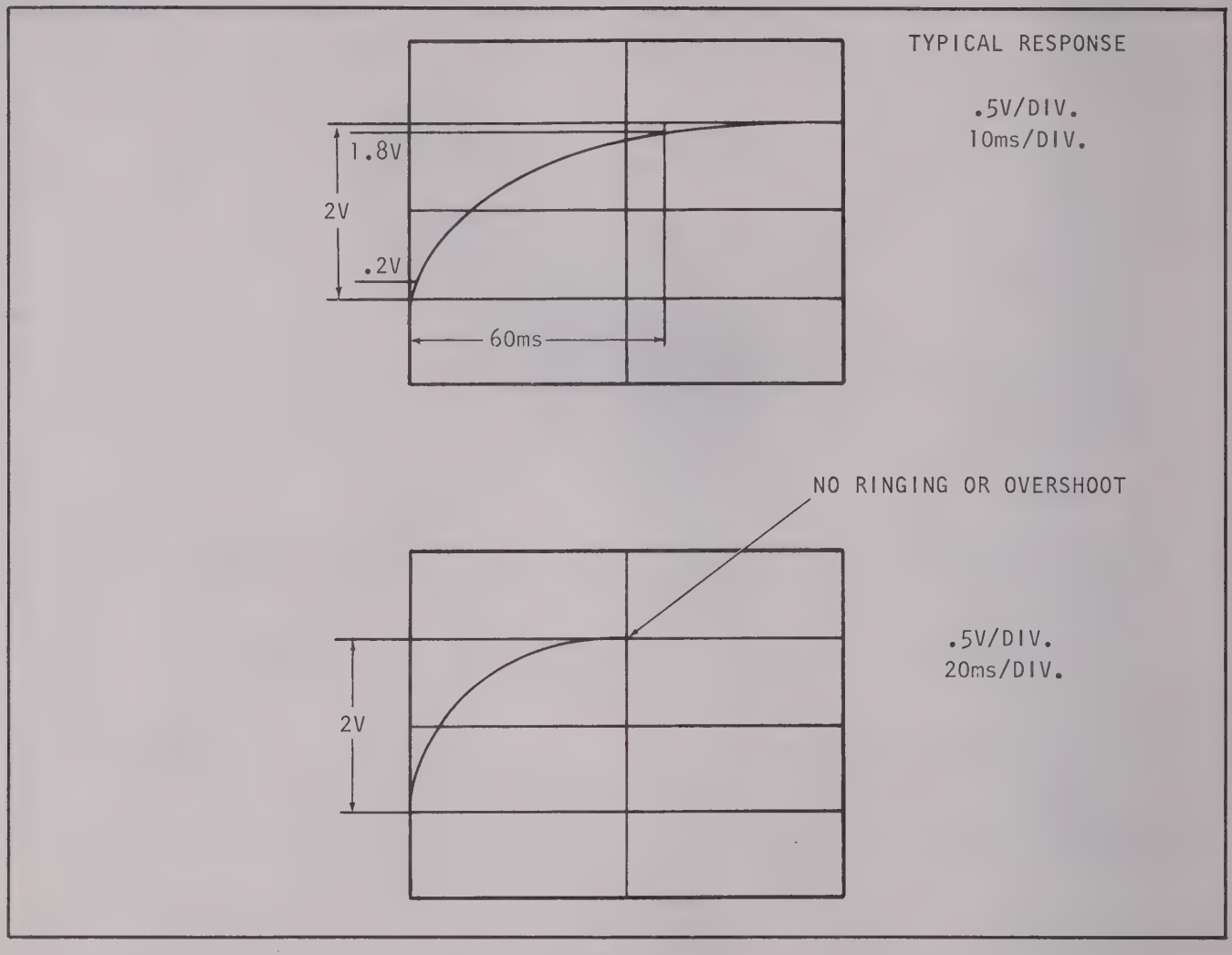


FIGURE 3-3. Model 480 Rise Time Test on 10nA Range

SECTION 4. ACCESSORIES.

4-1. GENERAL. This section describes the various accessories and options available for use with the Model 480 Picoammeter.

4-2. POWER OPTIONS. The Model 480 can be powered by line voltage (105-125 @ 50-60Hz standard) or the optional Model 1788 Rechargeable Battery Pack. (Optional line voltage range is described in Section 2.) The Model 1788 is available factory-installed or field-installable. Installation instructions are given in Section 2.

4-3. CABLES AND CONNECTORS. The following cables and connection kits enable effective use of the Model 480.

MODEL 4801 INPUT CABLE.

Description: The Model 4801 is a low-noise coaxial cable, 48 in. (1.2m) in length, with male BNC to male BNC connectors.

MODEL 4803 LOW NOISE CABLE KIT

Description: The Model 4803 consists of 50 ft. (15.2M) of low-noise coaxial cable with 10 BNC male connectors and 5 BNC female chassis-mount connectors.

4-4. TEST FIXTURES. The following test fixtures (shown in Figure 4-1) enable effective use of the Model 480 for the measurement application described.

MODEL 6104
TEST SHIELD

MODEL 6105
RESISTIVITY CHAMBER

FIGURE 4-1. Model 6104 and Model 6105 Test Fixtures

MODEL 6104 TEST SHIELD.

Description: The Model 6104 is a guarded and shielded test box for two-terminal or three-terminal connections. Voltages up to 1200V may be used. The Model 6104 provides excellent electrostatic shielding and high isolation resistance for the component under test. Clips plug into banana jacks allowing the user to fashion modified connections to suit the component to be tested.

Application: The Model 6104 is useable with the Model 480 picoammeter and Keithley voltage supplies, such as the optional Model 240A. When connected together as a system, using the cable and connector options, they form a complete test facility for measuring leakage current and other low current parameters for various test applications. A possible test set up is shown in Figure 4-2. The measurement sample would be connected between J1 and J7 or J8.

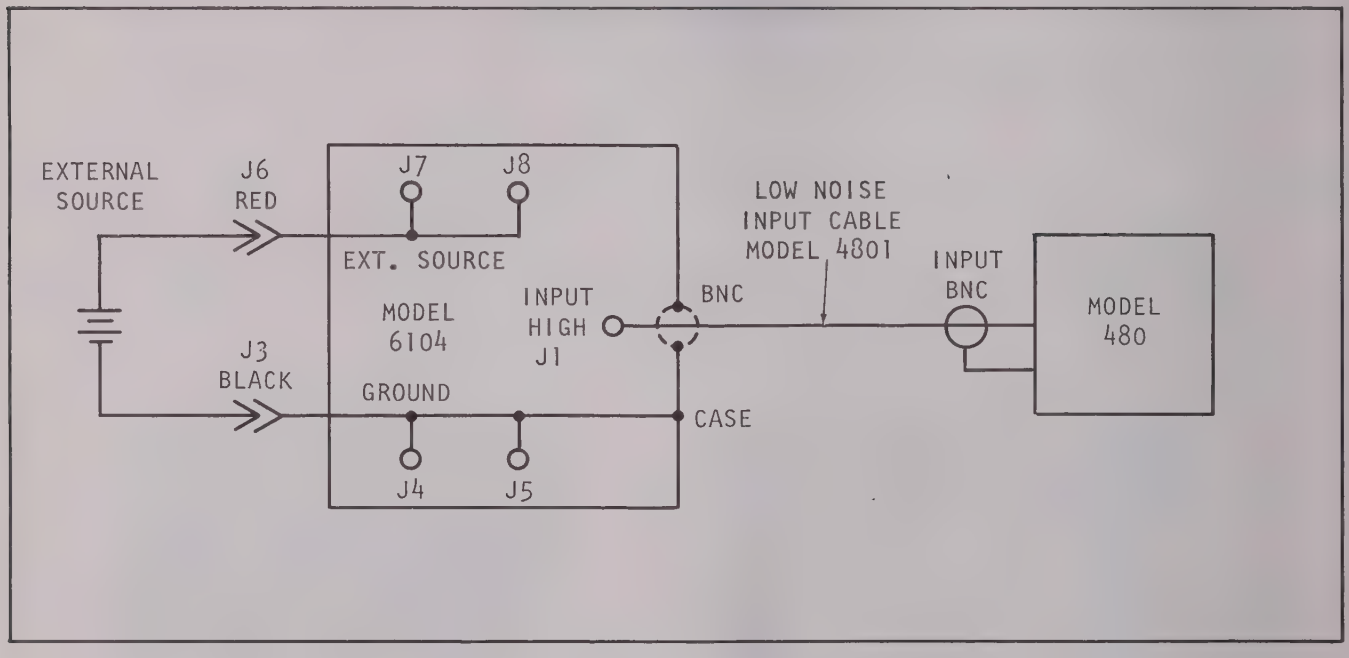


FIGURE 4-2. Model 6104 Test Set Up

MODEL 6105 RESISTIVITY CHAMBER.

Description: The Model 6105 is a guarded test fixture for measurement of surface and volume resistivities. The chamber is designed in accordance with ASTM Standard Method of Test for Electrical Resistance of Insulating Materials, D257-66. The 6105 can be used in conjunction with the Model 480 and a high voltage power supply, such as the Model 240A.

Application: Resistivity can be determined by measuring the current through a sample with a known voltage impressed. The Model 6105 can accommodate non-rigid sheet samples 2-1/2 inches (63mm) to 4 inches (102mm) in diameter and 1/4 inch (6mm) thick with excitation voltages up to 1000 volts. The Model 6105 has a UHF connector for the bias supply and a BNC output to the Model 480. A test hook up using the Model 240A power supply is shown in Figure 4-3.

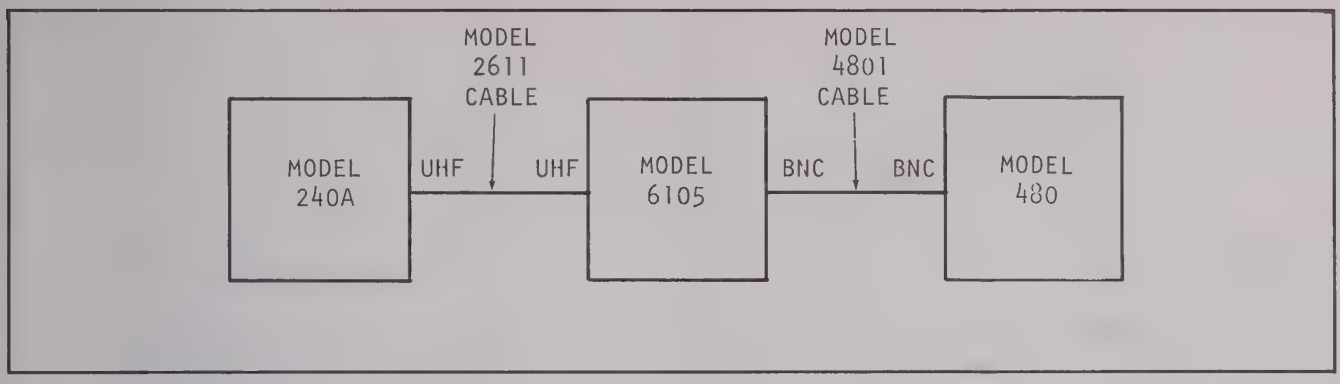


FIGURE 4-3. Resistivity Test Hook Up

4-5. POWER SUPPLY. The Model 240A High Voltage Supply, shown in Figure 4-4, is offered as an optional external bias voltage source useable with the Model 480. The Model 240A provides 0 to ±1200 volts dc, selectable in one volt steps, with output current limited to 10mA maximum. The output voltage is stable and accurate to ±1% for all settings. The output voltage is supplied to a front panel connector and a rear panel connector, wired in parallel. The connectors are teflon-insulated UHF type.

4-6. RACK MOUNTING. The Models 1010 and 1017 Rack Mounting Kits (shown in Figure 4-5) permit mounting one or two Model 480 instruments in a standard 19-inch rack for convenient viewing.

4-7. MODEL 1684 CARRYING CASE. The Model 1684 Carrying Case (shown in Figure 4-5) is a hard vinyl case with a fitted foam insert to help protect the Model 480 from damage. There is also room in the case for the instruction manual and other small accessories.

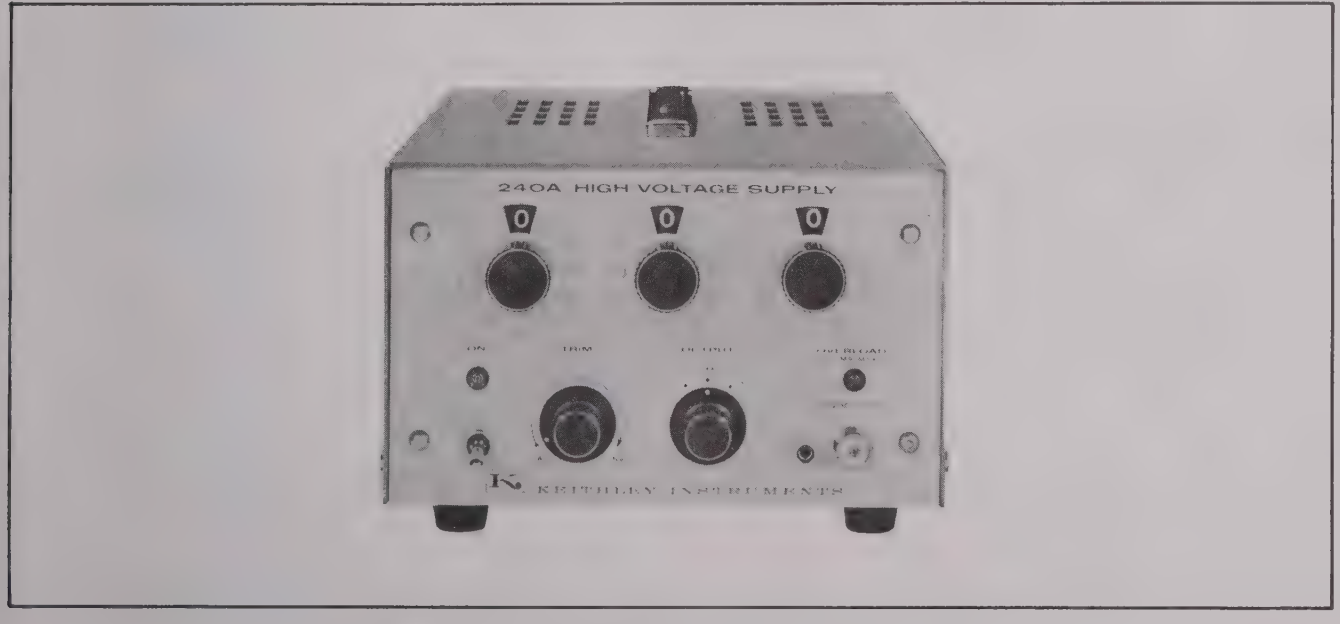


FIGURE 4-4. Model 240A High Voltage Supply

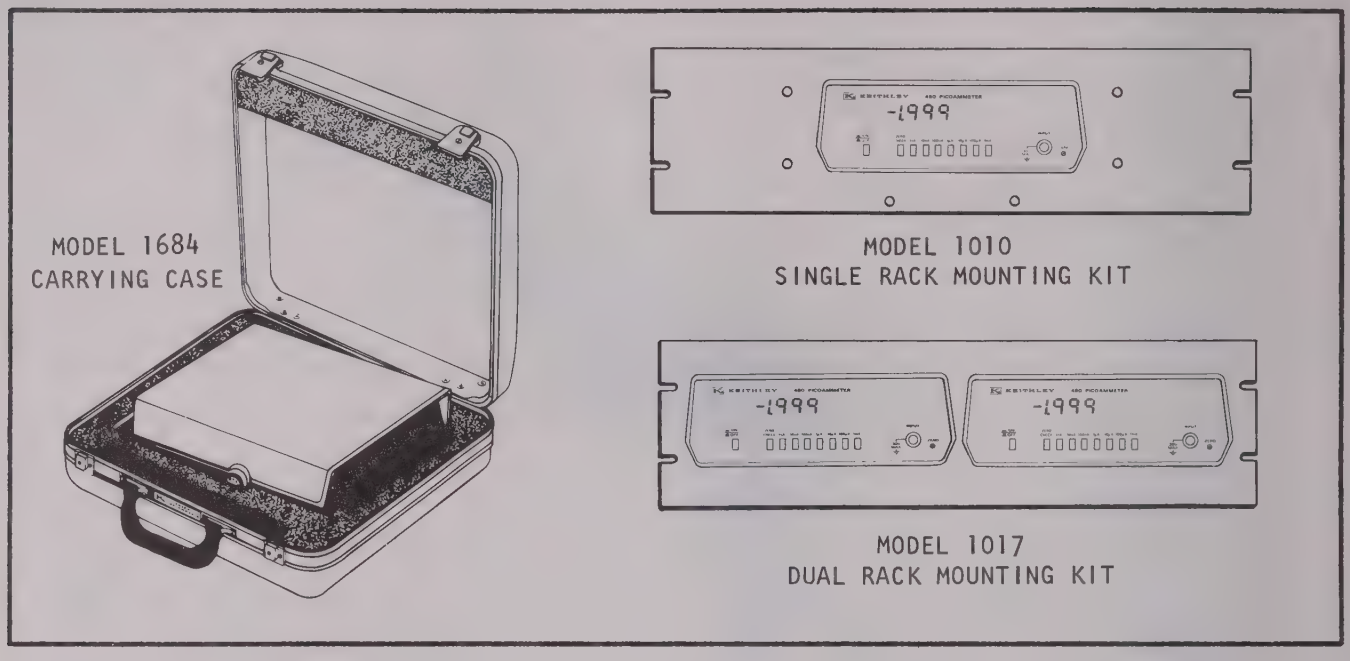


FIGURE 4-5. Carrying Case and Rack Mounting Kits.

SECTION 5. THEORY OF OPERATION.

5-1. GENERAL. This section contains circuit descriptions for the Model 480 Picoammeter and for the Model 1788 Battery Pack. An overall block diagram of signal flow is provided in Figure 5-1. The overall schematic diagram, drawing 29312E, is contained in Section 7.

5-2. OVERALL OPERATION. As shown in the Block Diagram, the Model 480 circuitry consists of a current-to-voltage converter, a 3-1/2 digit analog-to-digital converter and display and a power supply.

a. Current-to-Voltage Converter. The current-to-voltage converter consists of a feedback ammeter circuit with selectable precision feedback impedances to generate the seven current ranges. Ranges are selected using front panel pushbuttons. The voltage output from the converter is used to drive the analog-to-digital converter and is also presented as an analog output on the rear of the instrument.

b. A/D Converter. The Model 480 uses a 2-volt fullscale analog-to-digital (A/D) converter with a 3-1/2 digit multiplexed display. The A/D converter is a large scale integration (LSI) ratiometric device. Converter output is a multiplexed 4 digit binary coded decimal (BCD) number which is equal to the ratio of input voltage to an internal reference voltage. A separate clock circuit, not shown, supplies a 100kHz signal for converter timing and multiplexing the BCD output to the display.

c. Power Supply. The power supply circuits develop the internal operating voltages for the Model 480. These circuits may be powered either from line power or the optional Model 1788 Battery Pack.

5-3. CURRENT-TO-VOLTAGE CONVERTER. The voltage-to-current converter circuitry is shown in simplified form on Figure 5-2. Operational amplifier U104 is connected as a feedback amplifier with switch selectable feedback resistors. In this configuration, virtually

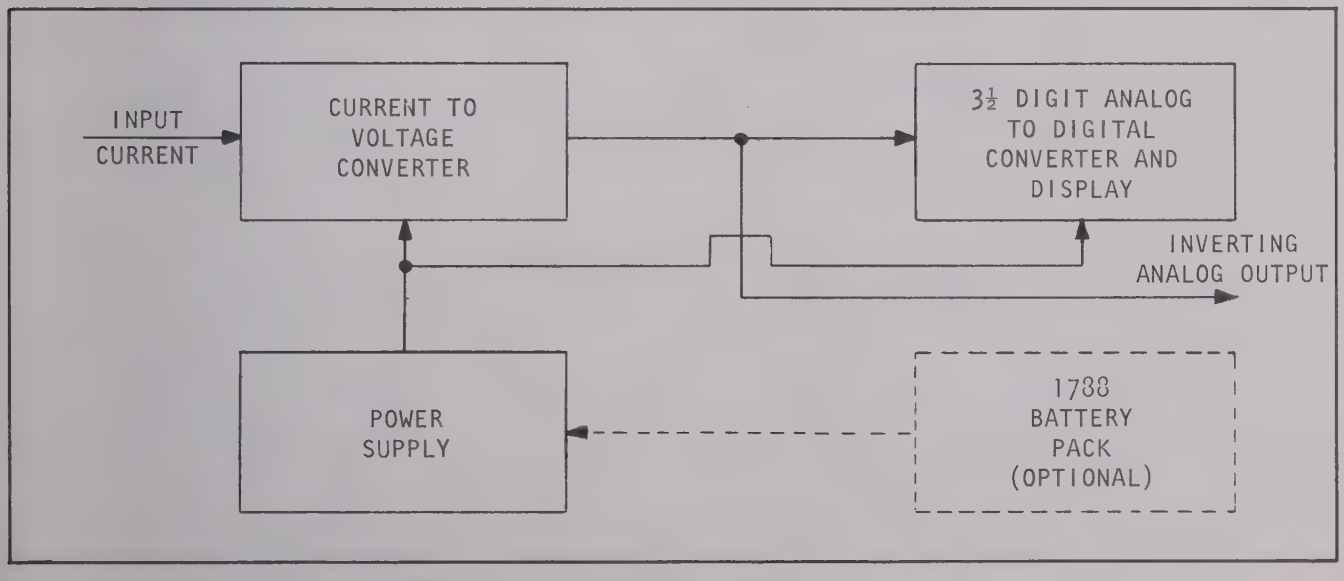


FIGURE 5-1. Model 480 Overall Block Diagram.

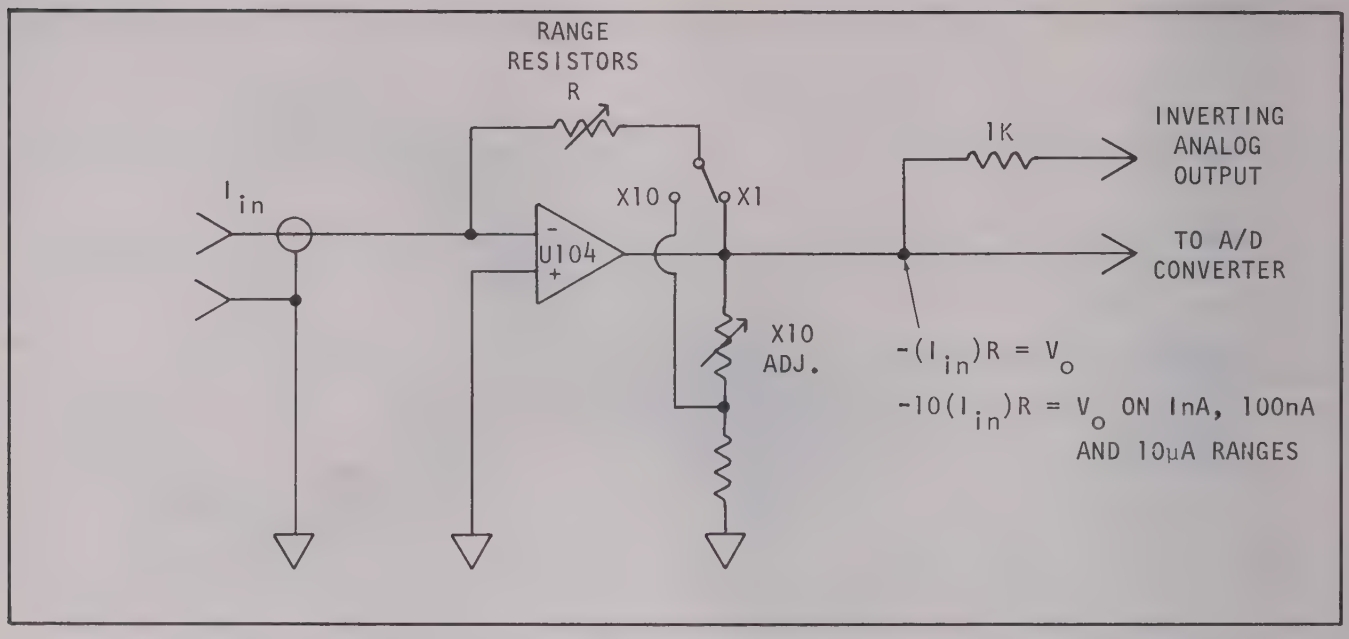


FIGURE 5-2. Simplified Schematic of Current to Voltage Converter.

all of the input current is forced through the feedback resistor and the linear transfer function of U104 is $-(I_{in})R=V_o$. On the 1nA, 100nA and 10μA ranges a divider is switched in which changes the function to $-10(I_{in})R=V_o$. This permits using only four separate feedback networks instead of seven and simplifies instrument calibration. On all ranges, the feedback resistance is selected such that a fullscale current input will result in a 1 volt output from the converter (e.g. $-(1mA) \times 1K\Omega = -1V$). Since the maximum display on all ranges equals fullscale plus 100% overrange minus one digit, the maximum output voltage from the converter for an on-scale reading is ±1.999 volts. The converter output voltage is used to drive the A/D converter and is also furnished through a 1KΩ resistor as Inverting Analog Output for external use.

a. Input Overload Protection. Converter input protection to U104 is provided by a 1 megohm resistor (R110), Q102 and Q103 (See Schematic 29312E). Q102 and Q103 limit the input voltage to one diode drop. R115, R116 and the two halves of JFET Q104 form a matched pair of source followers which buffer the signal and limit the input current to $\leq$ 0.5pA.

NOTE

Q104, R115, and R116 must be ordered and replaced as a matched set.

During input current overloads, zener diodes VR101 and VR102 limit the output voltage swing of U104 to approximately ±5 volts. These diodes, along with R118, protect U104 and the A/D converter with up to 20 volts continuously applied to the Inverting Analog Output. Capacitors C119 and C120 absorb the transient current surge during application of a 1000 volt, 10mA limited input overload.

b. Zero Check and Adjustment. Actuating the ZERO CHECK pushbutton, closes S107 and opens S103H. S107 shorts the feedback resistance of U104 which results in the offset of U104 being presented at its output. S103H inserts R104 into the A/D converter reference voltage divider which shifts the reference from 1 volt to approximately 100 millivolts. This serves to change the A/D converter from 2 volt fullscale to 200mV fullscale. This is necessary because whenever the output divider is used in the current converter, the input offset voltages are multiplied by ten. Since actuation of the ZERO CHECK switch disables the divider, it is necessary to add a gain of ten to the A/D converter to permit accurate zero adjustment during zero check.

5-4. A/D CONVERTER. The A/D converter operates on the dual slope principle and is comprised of two large scale integration circuits U101 and U103, plus their associated discrete components. It is important to note that internally the converter operates as a 4-1/2 digit converter with 20,000 counts fullscale. However, in the Model 480, the least significant digit is blanked, resulting in a 3-1/2 digit fullscale display of 2000 counts minus 1. The timing of the A/D converter is divided into 3 periods as described below.

a. Auto-Zero. The auto-zero period (A, Figure 5-3) is 100 milliseconds in length, which corresponds to 10,000 clock pulses. During this period, the reference voltage (V_{REF}) is stored on capacitor C102. Capacitor C105 stores $V_{REF} + V_{OS1} - V_{OS2}$.

b. Signal-Integrate. The signal-integrate period (B, Figure 5-3) is also 100 milliseconds in length. The A/D input is buffered and integrated by U103. Positive signals generate a negative-going ramp at the integrator output (Pin 14), while negative signals produce a positive-going ramp. The level of the integrated signal at the end of the signal - integrate period is proportional to the average of the applied signal during this period. Since signal integration continues for 100 milliseconds, the A/D converter exhibits high normal mode rejection for ac signals in multiples of 10 Hz, particularly 50 and 60Hz line frequencies.

c. Reference-Integrate. The reference-integrate period (C or D, Figure 5-3) is a maximum of 200 milliseconds or 20,000 counts in length. During this period, the integrator is returned to baseline level by applying a reference voltage of a polarity opposite to that of the signal. A positive-going ramp is obtained by grounding the buffer input, while a negative-going ramp is produced by the integration of $2 \times V_{REF}$ (that is, V_{REF} + the voltage stored on C102). The time, or number of clock pulses, required for discharge is the number of clock pulses required for the integrator to return to baseline level. The maximum count during this period is 20,000, which corresponds to a discharge period of 200 milliseconds or fullscale input. For an input of less than fullscale, the A/D automatically reverts to auto-zero for that period of the 200 milliseconds remaining after return to the baseline level. V_{REF} is provided by a divider connected to the internal reference supply of U103. The reference voltage is 1 volt for current measurements and 100 millivolts during zero check. Calibration of the A/D converter is accomplished by adjusting R102 for a reference voltage of 1.0000 ± 0.0008 volts.

5-5. DISPLAY. Four light-emitting diodes (LED) are driven by U202, which is a CMOS BCD-to-seven segment decoder/driver with bipolar current-sourcing outputs. Segment currents are limited to approximately 20 milliamperes peak by resistor network R202. The LED readout is a multiplexed, common-cathode configuration with Darlington array U201 sequentially sinking current from each digit. Blanking of the overrange digit is accomplished by gates U102A and U102B. Emitter-follower Q101 ensures that CMOS-compatible levels are maintained on U104A, pin 1, regardless of the loading of U201.

5-6. AC POWER SUPPLY. When the Model 480 is operated from ac line power, the power supply furnished +5, +15 and -15 volts from regulators VR103, VR104 and VR105, respectively. Full-wave rectified ac from bridge rectifier CR103 and rectifiers CR101 and CR102 is filtered by capacitors C112, C115, C117 and C118 and is applied to the linear voltage regulators.

5-7. MODEL 1788 BATTERY PACK. When the Model 1788 Battery Pack is installed in the Model 480, S101 must be set to the BAT position to provide additional secondary voltage for battery charging. S101 also switches the input to VR103 from bridge rectifier CR103 to battery BT301. Four 2-volt, 2.5 ampere-hour lead-acid cells supply approximately 9.8 volts at full charge. After six hours of use on battery power, the battery pack should be recharged to ensure long battery life.

a. Battery Charging Circuit. While the Model 480 is plugged into line power and the battery pack is installed, battery charging proceeds as follows:

1) Full-wave rectified voltage from CR103 is applied to the anode of Q301, which is an SCR which regulates charging voltage. When Q301 is triggered on by a sufficient gate-cathode voltage differential, the batteries receive charge. Charging continues as long as the bridge output voltage exceeds battery voltage by 1 volt or more. Resistor R304 limits charging current when recharging a set of completely discharged cells. A filtered positive output from CR102 (or T301) provides the necessary gate turn-in bias through R306 and diode CR301. Resistor R303 ensures proper high-temperature operation of Q301.

2) When the battery voltage reaches the preset float voltage of 9.8 volts, zener VR301 conducts sufficient current to turn on Q302 and thus remove the gate trigger voltage from Q301. Float voltage is adjusted with R301. This is a factory adjustment which will normally not need field readjustment.

b. Battery Operation and Shutdown Circuit. The Model 480 operates as follows on battery power:

1) When the power is turned on, the batteries are connected to the input of VR103 to supply +5 volts for the logic, display and the clock circuit. The clock output is applied to the A/D converter as described in Paragraph 5-4, and to U301 which is a divide-by-four binary counter. The outputs of U301 drive a dc-to-dc inverter which is synchronized to the A/D converter to filter out inverter noise. The 25 kHz operating frequency is optimal for small transformer size and results in low switching losses. Blocking capacitors C301 and C302 protect Q307 and Q308 from damage if the drive is lost. Two half-wave rectifiers (CR304 and CR305) on the secondary of T301 provide rectified ac to filter capacitors C304 and C305, which provide power to +15 and -15 volt regulators VR104 and VR105.

2) To prevent permanent loss of battery capacity caused by deep discharge, a shutdown circuit stops operation on battery power when the battery voltage drops below approximately 7.2 volts. Shutdown is performed by micropower voltage detector U302. The open-collector output (U302, pin 4) saturates low and turns off pass transistor Q309 when the input voltage (at U302, pin 3) drops below 1.15 volts (typical). Resistor R314 provides sufficient hysteresis to prevent discharge from resuming when the battery voltage rises following disconnection of the load.

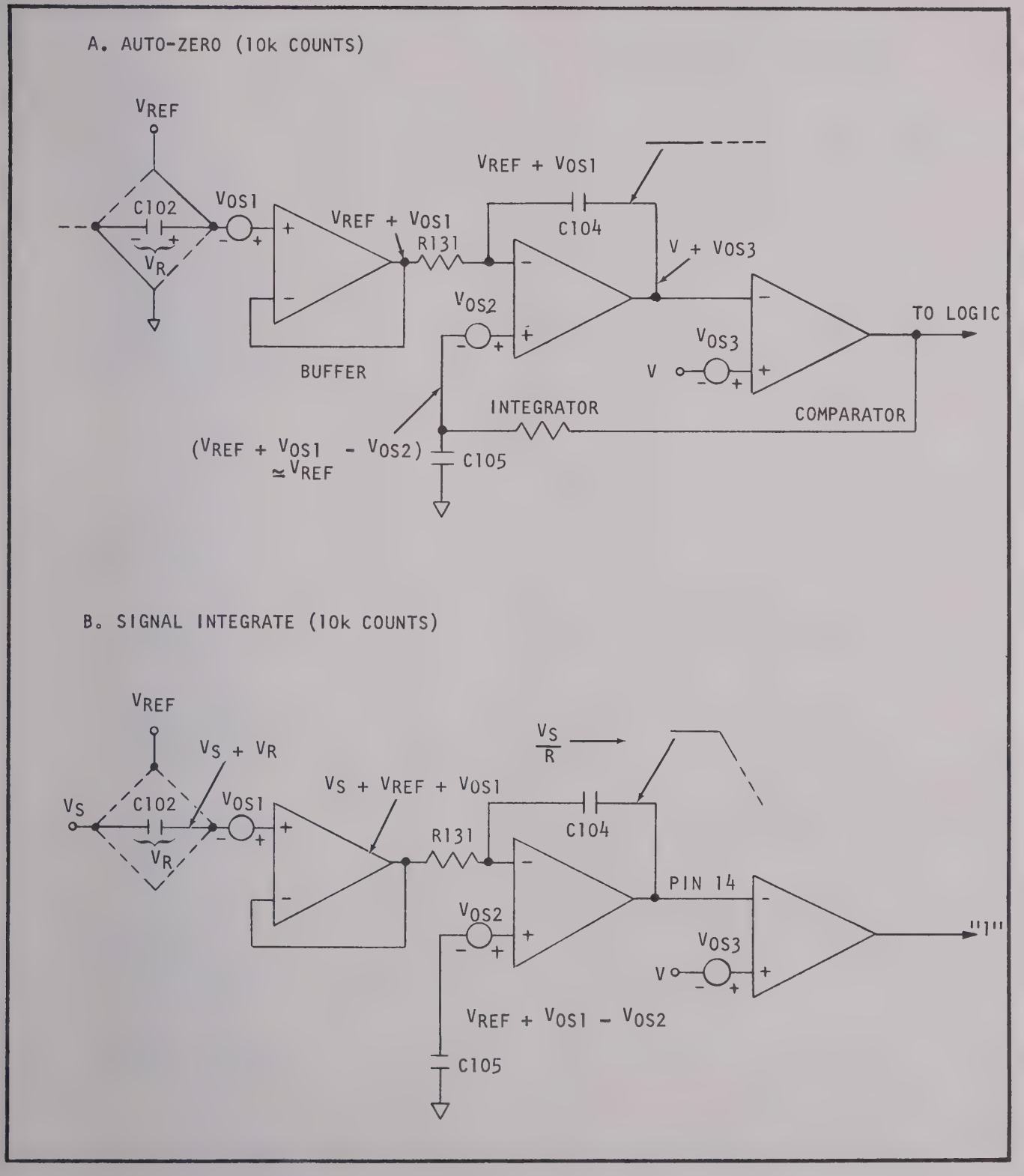
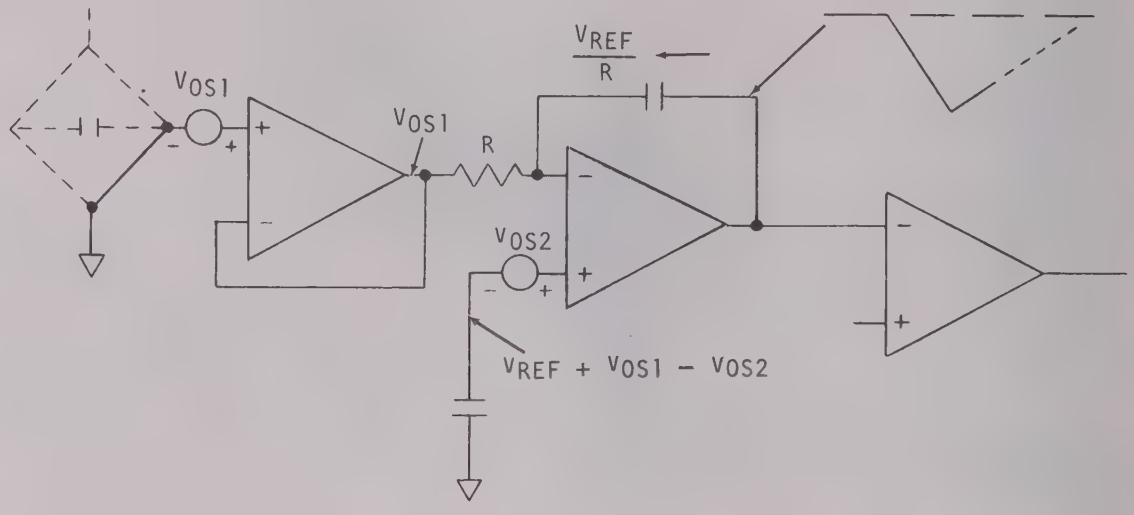


FIGURE 5-3. A/D Converter Function (Sheet 1 of 2)

C. NEGATIVE REFERENCE INTEGRATE (20k COUNTS AT FULL SCALE)
(POSITIVE INPUTS-TO A/D)



D. POSITIVE REFERENCE INTEGRATE (20k COUNTS AT FULL SCALE)
(NEGATIVE INPUTS TO A/D)

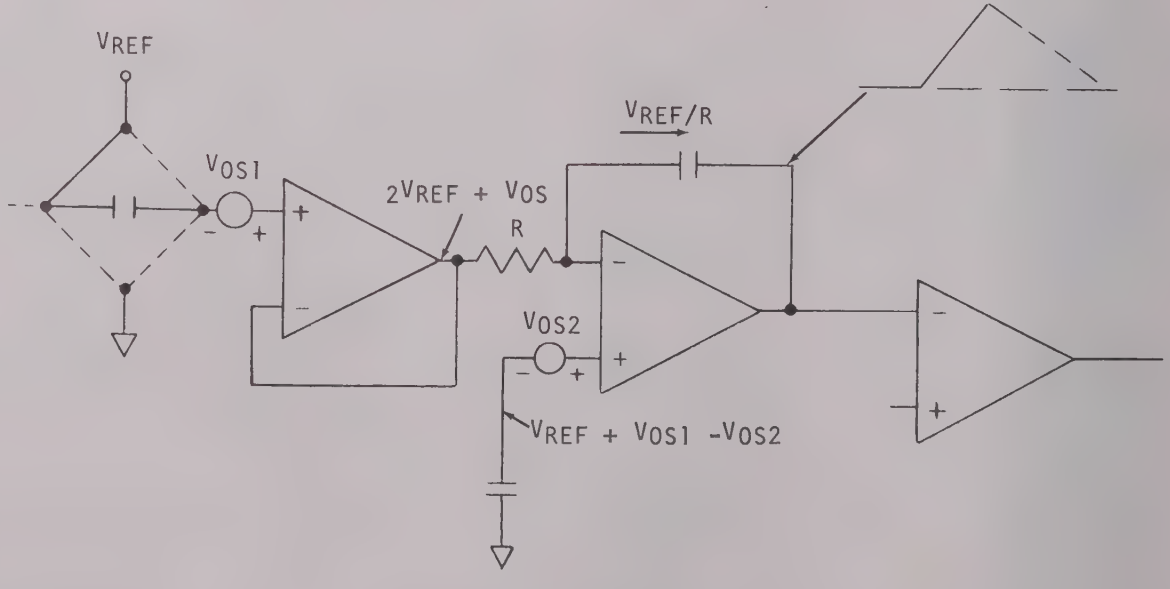


FIGURE 5-3. A/D Converter Function (Sheet 2 of 2)

SECTION 6. MAINTENANCE

6-1. GENERAL. This section provides calibration and troubleshooting information for the Model 480 and Model 1788 Battery Pack. Calibration should be performed yearly (every 12 months) or whenever performance verification (see Section 3) indicates that the Model 480 is out of specifications. If any step in the calibration procedure cannot be performed properly, refer to troubleshooting information in this section, or contact your Keithley representative or the factory as described in Section 3.

NOTE

Calibration should be performed by qualified personnel using accurate and reliable test equipment.

6-2. RECOMMENDED TEST EQUIPMENT. Recommended test equipment for calibration and troubleshooting is listed in Table 6-1. Alternate test equipment may be used. However, the accuracy of the alternate test equipment must be at least 10 times better than the instrument specification, or equal to Table 6-1 specifications.

Table 6-1.
Recommended Test Equipment for Calibration and Troubleshooting.

ITEM	DESCRIPTION	SPECIFICATION	MFR.	MODEL
A	DC Calibrator	1.900000V, 190.0000V, to within 0.002% or 20μV.	Fluke	343A
B	Multimeter, Digital	1.9V ± .5mV, 0.00mV ± 0.05mV, 1.0000V ± 800μV, to within 0.013% of reading. 0-500mA.	K-1	172
C	Precision Shielded Resistors (See Fig. 3-1).	10KΩ ± 175 ppm, 10MΩ ± 300 ppm, 100MΩ ± 2000 ppm, @ 25°C ± 3°C.	--	--
D	Picoampere Source (used for troubleshooting only).	10.00×10^{-5} thru 10^{-7} ± 0.25%, 10.00×10^{-8} ± 0.5%, 10.00×10^{-9} ± 0.8%.	K-1	261

6-3. ENVIRONMENTAL CONDITIONS. Calibration should be performed under laboratory conditions having an ambient temperature of 20° to 26°C (68° to 78°F), and a relative humidity of less than 70%.

6-4. CALIBRATION PROCEDURE. Perform the following adjustments to calibrate the Model 480 and restore its operation to specified limits.

a. Battery Pack Removal. If the Model 1788 Battery Pack is installed in the instrument it must be removed to gain access to internal adjustments and test points.

WARNING

Disconnect the line cord before removing the case cover.

1. Turn off the power and disconnect the line cord. Remove the four screws from the bottom of the case and separate the top cover from the bottom cover.

2. Push back the ground clip (shown in Figure 2-2) from the upper side of the battery pack and remove the battery pack from the spacers.

3. Calibration may be performed on battery power as long as the battery pack is sufficiently charged. Leave the battery pack plugged into the instrument, but set the battery pack behind the DMM on the bench or table. If the battery pack is not sufficiently charged, operate from line power.

b. Warm Up. Turn the Model 480 on and allow a one-half hour warm up time.

NOTE

If the instrument has been subjected to extremes of temperature, allow the internal temperatures to stabilize for a minimum of one hour at the environmental conditions specified in paragraph 6-3.

c. Reference Adjustment. Calibrate the A/D converter as follows:

1. Connect the LO lead of the DMM (B) to INVERTING ANALOG OUTPUT-COMMON.

2. With the HI DMM lead on TP4, adjust R102 for 1.0000V ± 0.0008V reading on DMM. See Fig. 6-1 for test point and adjustment locations.

d. Zero Adjustment.

1. Connect DMM (B) to INVERTING ANALOG OUTPUT.

2. Set 480 to 10µA range, depress ZERO CHECK to latch position.

3. Adjust R101 (front panel ZERO) for a DMM reading of 0.00mV ± 0.05mV.

4. Unlatch ZERO CHECK.

e. Gain Adjustment, 10µA and 100µA Ranges.

1. Connect test fixture output to Model 480 and connect 343A DC Calibrator (A) output to the test fixture input. (See Fig. 3-1 for set up).

2. Set 480 to 100µA range.

3. Set test fixture to 10KΩ and POS polarity postions.

4. Set 343A to 1.900000V and output to ON position.

5. Record INVERTING ANALOG OUTPUT voltage displayed on DMM. Verify Model 480 display indicates 190.0 ± 5 digits.

6. Set test fixture to 10MΩ position, POS polarity.

7. Set 480 to 10µA range.

8. Set 343A to 190.0000, output ON.

9. Adjust R121 for same reading on DMM as noted in step 5 ± .0005V. Verify 480 display indicates 19.00 ± 5 digits.

f. 10nA Range Adjustment.

1. Set 343A to 1.900000V, output ON.
2. Set test fixture to 100MΩ position, POS. polarity.
3. Set 480 to 10nA range.
4. Adjust R124 for a 480 display indication of 19.00nA ± 0 digits.

g. Verification. After completing the calibration procedures, the Performance Verification tests in Section 3 may be performed to ensure that the Model 480 operation is within specifications.

6-5. TROUBLESHOOTING OVERVIEW. The troubleshooting instructions contained in this section are intended for qualified personnel having a basic understanding of analog and digital electronic principles and components used in a precision electronic test instrument. Instructions have been written to assist in isolating the defective circuit or subcircuit. Isolation of the specific defective component has been left to the technician.

6-6. TROUBLESHOOTING PROCEDURE. This section contains tables listing step-by-step checks of the major Model 480 circuits described in Section 5, Theory of Operation. Proceed as follows:

a. In general, start troubleshooting with Table 6-2, Line Power Checks, to verify that the power supplies are providing the specified voltage to the electronic components.

TABLE 6-2.
Line Power Checks

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1	S105 line switch	Must be set to 105-125V or 210-250V as appropriate.	
2	S101 LINE/BAT switch	Must be set to BAT for use with battery pack.	
3	F101 line fuse	Continuity.	
4	P1008 line cord	Plugged into live receptacle.	
5	S108 OFF/ON power switch.	Turn on power.	
6	+5V pad*	+5 volts ±10%.	Output of VR103.
7	TP2*	+7 volts minimum.	Output of CR103, input to VR103.
8	+15V pad*	+15 volts ±10%.	Output of VR104.
9	TP10*	+17.5 volts minimum.	Output of CR102, input to VR104.
10	-15V pad*	-15 volts ±10%	Output of VR105.
11	TP1*	-17.5 volts minimum.	Output of CR101, input to VR105. NOTE: Hot regulator may indicate shorted load.

* On main printed circuit board (see Figure 6-1 for location).

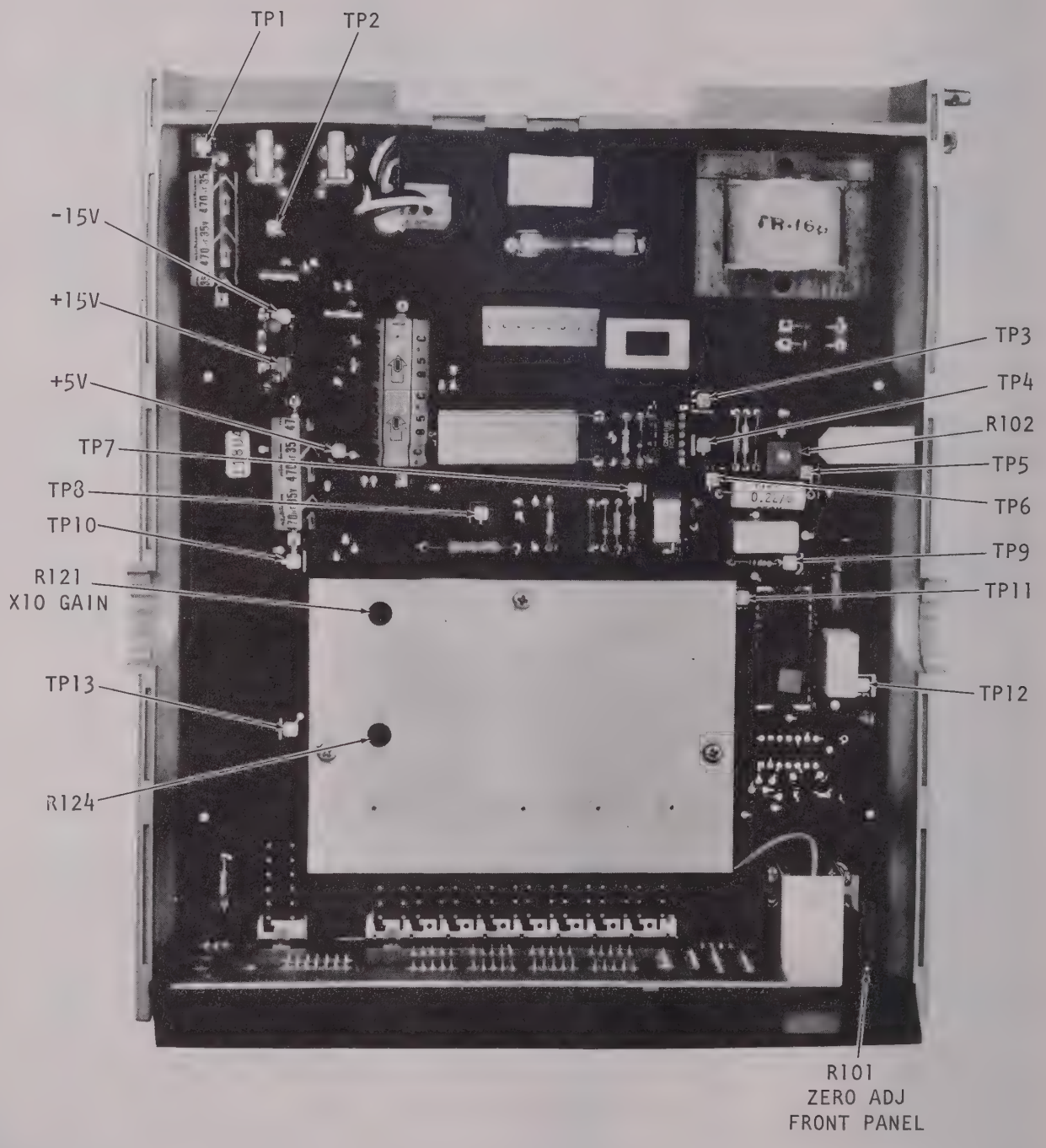


FIGURE 6-1. Test Point and Adjustment Locations

TABLE 6-3.
Battery Power Checks.

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Check AC line power per Table 6-2.	
2		Turn off power.	
3	S101 line/bat switch.	Move to BAT.	
4	P1008 line cord.	Plugged into live receptacle.	Charge circuit checks.
5	F301	Remove fuse and connect DMM to fuse clip. 0 to 500mA charging rate, varies with line voltage and battery state of charge.	No charge, see step 5A. Correct charging but short battery operating time, see step 6.
5A	BT301 batteries	Full charge is ≈9.8 volts over 4 cells. R301 adjusts charging rate (float voltage).	If voltage is low & adjustment of R301 does not start charging, see steps 7 & following. If voltage is low & adjustment of R301 does start charging, see Table 6-7 for adjustment of battery charge voltage.
6	Each battery cell voltage during charging.	Less than 3 volts for any cell.	High voltage or zero indicates damaged cell.
7	Q301 anode.	Full wave rectified voltage, 15 VDC nominal.	Output of CR105.
8	C304 +	+17.5 volts minimum.	Output of CR102. Triggers Q301 gate thru R306 and CR301 unless Q302 is on.
9	Q302	Should saturate only when battery approaches full charge.	
10	VR301	8.2V zener.	
11		Unplug line cord and turn power on.	Discharge checks.
12	P1004 pin 8 or U301 pin 11.	100 kHz; 5V square wave.	Clock input. If no input, see step 12A.
12A	TP2*	+7 volts minimum.	Battery voltage input to VR103.
13	Q307 and Q308 base.	Square wave, ±0.7 volts at 25 kHz.	Output of U301, ÷ 4.
14	Q307, Q308 collector.	Must oscillate from saturation to twice battery voltage (≈19 volts) at 25 kHz.	Inverter.
15	C304, C305	±17.5 volts minimum (±25 volts typical with full charge batteries).	Inverter output; Input to VR104 and VR105.

* On main printed circuit board (see Figure 6-1).

b. If trouble occurs on battery power only, or if battery operating time is substantially less than 6 hours after overnight charging, test the batteries and charging circuit per Table 6-3.

c. Proper operation of the A/D converter and display should be verified before troubleshooting the current-to-voltage converter. Check these circuits per Tables 6-5 and 6-4, respectively.

d. Check the current-to-voltage converter circuitry per Table 6-6.

e. Table 6-7 provides instructions to adjust the Model 1788 Battery Pack float voltage. This voltage is preset at the factory and readjustment in the field will normally not be required.

f. Unless otherwise specified, all measurements are referenced to COMMON of the INVERTING ANALOG OUTPUT and/or battery pack ground clip.

TABLE 6-4.
Display

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Turn on power and select any range.	
2	+5V*	+5 volts ±10%.	If low, check per Table 6-2.
3	U201, pins 1, 2, 6 and 7.	Digit drive. Low = enabled.	LED cathode.
4	U202, pins 1, 2 6 and 7	HI = enabled.	BCD input to U202 segment decoder/drive.
5	U202, pin 4.	Positive-going signal lasting for 200 clock pulses.	Leading digit suppression. Output of U102A.
6	J1003, pin 8	Polarity line (sign). HI = off LO = -	
7	J1007, pins 3, 4 and 5.	Appropriate DP line high (on).	Depress applicable range pushbuttons to verify all DP lines.

* On main printed circuit board (see Figure 6-1).

TABLE 6-5.
A/D Converter.

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Turn on power. Select 1mA range. Open circuit to INPUT of 480.	
2	Display	.000	
3	TP9*	0.000 ± 100μV.	Input to U101. If different, check I/V converter Table 6-6.
4	TP4*	+1.0000 ± 0.0008V	Reference output. Calibration point.
5	TP3*	0 to +5 volt square wave at 100 kHz.	Clock input to A/D converter.
6	TP11*	+1.0 ±0.1 volts.	Stored autozero voltage.
7	U103, pin 11	+1.0 ±0.1 volts.	Σ-node voltage to integrator in U103.
8	TP5*	-1.2 ±0.2 volts.	U103 integrator output voltage.
9	U103, pin 13	+1 volt.	U103 buffer input.
10	TP7*	+1 volt.	U103 buffer output.
11		Connect TP4* to TP9*	
12	Display.	1.000 ± 1 digit.	If different, check U101 input.
13	TP9*	1.0000 volt, reference	Input to U101
14	TP5*	Waveform per Figure 6-2.	Integrator output.
15	U103-2	Waveform per Figure 6-2. during ramping of integrator output.	Comparator output.

* On main printed circuit board (see Figure 6-1).

NOTE

The Current Source (D) used in Table 6-6 can not be used to either verify Model 480 accuracy specifications or calibrate the instrument.

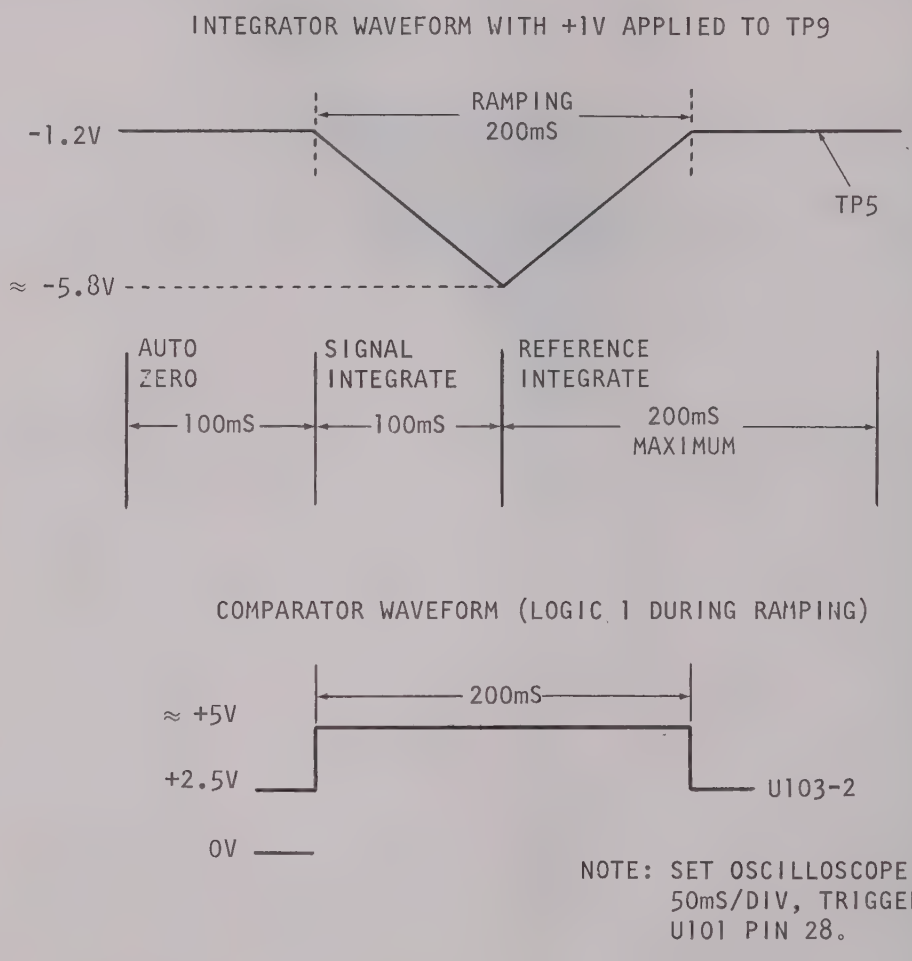


FIGURE 6-2. Integrator and Comparator Waveforms.

TABLE 6-6.
Current-to-Voltage Converter.

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Turn on power. Select 10μA range. Depress ZERO CHECK & adjust front panel ZERO R101.	
2	TP8*	00.00mV ± 0.05mV.	U104 offset, S107, R101, input buffer circuit.
3		Release ZERO CHECK. Select 100μA range.	
4	External current source (D).	Apply 10.00×10^{-5} A.	
5	TP8*	-1.000 V ± 7.5mV, Typical.	U104 and feedback components: R113, R120, C109, C120, S103C, S104.
6	External current source (D).	Apply 10.00×10^{-5} A. Select 1mA range.	
7	TP8*	-100mV ± 0.75mV, Typical.	U104, R107, C107, S102
8	External current source (D).	Apply 10.00×10^{-6} A. Select 10μA range.	
9	TP8*	-1.000V ± 7.5V, Typical.	U104, R113, R121, R122, R123, C109, C119, S103C and S104.
10	External current source (D).	Apply 10.00×10^{-7} A. Select 1μA range.	
11	TP8*	-1.000V ± 7.5mV, Typical.	U104, R117, C110, S106 and S103E.
12	External Current source (D).	Apply 10.00×10^{-8} A. Select 100nA range.	
13	TP8*	-1.00V ± 10mV, Typical.	U104, R117, C110, S106 and S103E.
14	External current source (D).	Apply 10.00×10^{-9} A. Select 10nA range.	
15	TP8*	-1.000 V ± 16mV, Typical.	U104, R119, R124, S103F, and S103G.
16	External current source (D).	Apply 10.00×10^{-9} A. Select 1nA range.	
17	TP8*	Approximately -5 volts.	Input current overload due to action of X10 divider. Zener VR101 clamps U104 output to ≃ -5V.

* For convenience, Inverting Analog Output may be used.

TABLE 6-7.
Adjustment of Battery Charge Voltage.

STEP	ITEM/COMPONENT	REQUIRED CONDITION	REMARKS
1		Instrument off.	
2	R301	Turn full CCW. (maximum charge rate).	
3	BT301	Monitor battery voltage for > 9.8V.	Fully charged cells require several minutes to reach this level. Discharged cells require several hours. ⚠ CAUTION - charging to > 10V for longer than 30 minutes will reduce battery life.
4	R301	When cells reach 9.8V, turn DMM on and adjust to maintain 9.8V across BT301.	

SECTION 7. REPLACEABLE PARTS.

7-1. GENERAL. This section contains information for ordering replacement parts. Panels and covers are shown separately on Figure 7-1. The Replaceable Parts List is arranged in alphabetical order of the Circuit Designations of the components. A cross-reference list of manufacturers, containing their addresses, is given in Table 7-1.

7-2. ORDERING INFORMATION. To place an order or to obtain information concerning replacement parts, contact your Keithley representative or the Factory. See the inside front cover for addresses. When ordering, include the following information:

a. Instrument Model Number.

b. Instrument Serial Number.

c. Part Description.

d. Circuit Designation (if applicable).

e. Keithley Part Number.

7-3. FACTORY SERVICE. If the instrument is to be returned to the factory for service, please complete the Service Form which follows this section and return it with the instrument.

7-4. SCHEMATIC.

a. Model 480 3-1/2 Digit Picoammeter: Schematic No. 29312E (Page 7-9). This schematic also describes the Model 1788 Rechargeable Battery Pack.

7-5. COMPONENT LAYOUT.

a. Model 480 Component Layout PC-472 No. 29314D (Page 7-10).

b. Display Board PC-473 Component Layout (Page 7-11).

c. Model 1788 Rechargeable Battery Pack Component Layout PC-451 (Page 7-12).

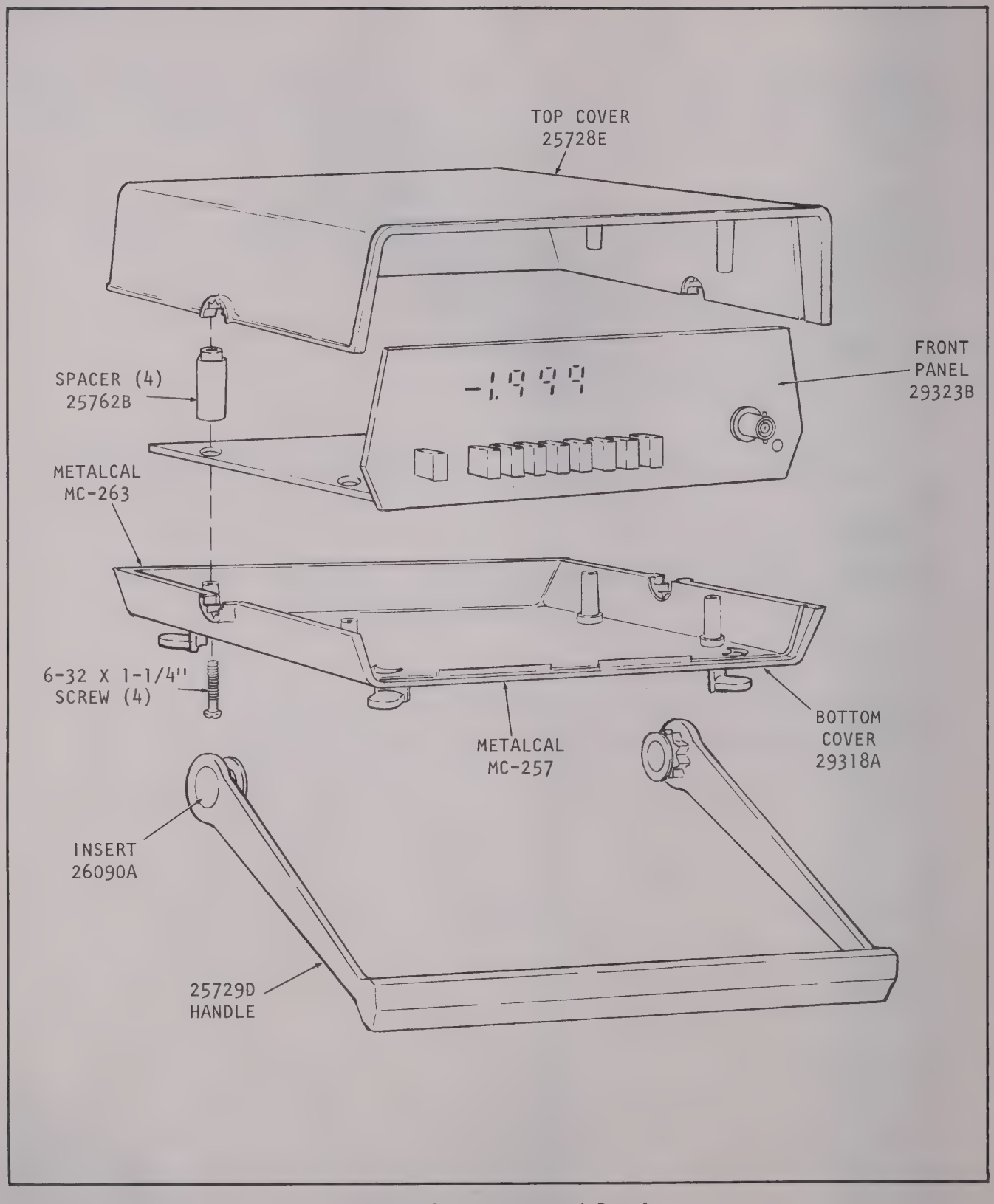


FIGURE 7-1. Covers and Panels

TABLE 7-1.
Cross-Reference of Manufacturers

MFR. CODE	NAME AND ADDRESS	FED. SUPPLY CODE
A-B	Allen-Bradely Corp. Milwaukee, WI 53204	01121
AMP	Amphenol Broadview, IL 60153	02660
A-P	A-P Products Painsville, Ohio	
BEC	Beckman Inst. Inc. Fullerton, CA 92634	73138
C-I	Components, Inc. Biddeford, ME 04005	06751
C-W	Continential-Wirt Elec. Corp. Warminster, PA 18974	79727
CLB	Centralab Division. Milwaukee, WI 53201	71590
DLE	Dale Electronics, Inc. Columbus, NE 68601	91637
ECI	Electro Cube Inc. San Gabriel, CA 91776	14752
EDI	Electronic Devices, Inc. Yonkers, NY 10710	83701
F-I	Fairchild Inst. Corp. Mountain View, CA 94043	07263
INT	Intersil Inc. Cupertino, CA 95014	32293
IRC	IRC Division Burlington, IA 52601	07716
K-I	Keithley Instruments, Inc. Cleveland, Ohio 44139	80164
L-F	Littlefuse, Inc. Des Plaines, IL 60016	75915
MEP	Mepco Inc. Morristown, NJ 07960	80031
MOL	Molex Downers Grove, IL 60515	75915
MOT	Motorola Semi. Prod. INC. Phoenix, AZ 85008	04713
NCI	National Components, Inc. West Palm Beach, FL	
NEL	Northern Engr. Labs. Burlington, WI 53105	00815
POT	Potter Company Chicago, Illinois 60693	
RCA	RCA Corporation Moorestown, NJ 08050	02734
SHR	Sheridan Sales, Inc. Cincinnati, Ohio 45222	
T-I	Texas Instruments, Inc. Dallas, TX 75231	01295
TEP	Tepro Electric Corp. Rochester, NY 14606	02985

REPLACEABLE PARTS LIST

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
	CAPACITORS (C) "100" Series (Sch. 29312E-Pg.7-9) (PC-Board 472-Pg.7-10)					
C101	.1µF, ±10%, 100VDC	J-4	2/D1	AMP	C280AE/P100K	C-188-.1
C102	1µF, ±10%, 100VDC	K-3	3/D1	POT	4309C-105K	C-294-1
C103	NOT USED					
C104	.22µF, 10%, 200VDC	M-1	5/C2	POT	22-200-10-X363UW	C-269-.22
C105	1µF, ±10%, 100VDC	L-3	6/D2	POT	4309C-105K	C-294-1
C106	.01µF, 16V, CerD	K-2	7/D2	CLB	UK16-103	C-238-.01
C107	.25µF, ±20%, 400VDC	F-3	8/E2	POT	0100SM1A	C-73-.25
C108	100pF, 1000V, CerD	E-4	9/C3	CLB	DD-101	C-64-100pF
C109	.022pF, ±20%, 600VDC	F-3	10/E3			C-220-.022
C110	2200pF, ±5%, 500VDC	F-2	11/E3	CLB	CPR-2200pF	C-138-2200pF
C111	2200pF, 1000V, CerD	F-4	12/D3	CLB	10SS-D22	C-64-2200pF
C112	2200µF, 15V, EAL	C-7	13/C4	NAC	16FLA2200	C-290-2200
C113	NOT USED					
C114	220pF, ±5%, 500VDC	F-2	15/E4	CLB	CPR-220pF	C-138-220pF
C115	4.7µF, 20V, ETT	D-7	16/C4	NCI	KNS475A020K	C-179-4.7
C116	22µF, ±20%, 10V	D-7	17/C4	C-I	TSD2-10-226	C-180-22
C117	470µF, 35V, EAL	C-8	18/B5	SHR	35ELA470	C-289-470
C118	470µF, 35V, EAL	C-7	19/C5	SHR	35ELA470	C-289-470
C119	1µF, 100V, My	H-1	20/D4	ECI	230B1B105	C-245-1
C120	1µF, 100V, My	G-3	21/E4	ECI	230B1B105	C-245-1
C121	10µF, 20V, ETT	D-8	22/C5	NCI	KNS106B020K	C-179-10
	"300" Series (Sch. 29312E-Pg.7-9) (PC-Board 451-Pg.7-12)					
C301	4.7µF, 20V, ETT	G-7	3/E3	NCI	KNS475A020K	C-179-4.7
C302	4.7µF, 20V, ETT	G-7	2/E3	NCI	KNS475A020K	C-179-4.7
C303	1.0µF, 250V, MPY	H-7	4/E3	AMP	C280AE/A1M	C-256-1
C304	100µF, 35VC	E-7	6/F4	NIC	35-ULA-100	C-295-100
C305	100µF, 35VC	E-8	5/F3	NIC	35-ULA-100	C-295-100

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
	DIODES (CR) "100" Series (Sch. 29312E-Pg.7-9) (PC-Board 472-Pg.7-10)					
CR101	Rectifier, 1A, 800V	B-7	26/C1	MOT	1N4006	RF-38
CR102	Rectifier, 1A, 800V	B-7	27/C1	MOT	1N4006	RF-38
CR103	Bridge Rectifier, 100V, 2A	B-6	28/C2	EDI	PD10	RF-36
CR104	Rectifier, 75mA, 75V	L-1	29/D3	T-I	1N914	RF-28
CR105	Rectifier, 75mA, 75V	L-1	30/D4	T-I	1N914	RF-28
	"300" Series (Sch. 29312E-Pg.7-9) (PC-Board 451-Pg.7-12)					
CR301	Rectifier, 75mA, 75V	E-6	26/D4	T-I	1N914	RF-28
CR302	Rectifier, 75mA, 75V	G-7	28/E3	T-I	1N914	RF-28
CR303	Rectifier, 75mA, 75V	G-7	27/E3	T-I	1N914	RF-28
CR304	Rectifier, 75mA, 75V	F-7	30/F4	T-I	1N914	RF-28
CR305	Rectifier, 75mA, 75V	F-8	29/F4	T-I	1N914	RF-28

DISPLAYS (DS)
"200" Series (Sch. 29312E-Pg.7-9)
(PC-Board 473-Pg.7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
DS201	±1 LED Digit	K-7	3/D3	F-I	FND561	DD-17
DS202	7-Segment LED Digit	L-7	4/D3	F-I	FND560	DD-16
DS203	7-Segment LED Digit	L-7	5/D3	F-I	FND560	DD-16
DS204	7-Segment LED Digit	L-7	6/E3	F-I	FND560	DD-16

FUSES (F)
"100" Series (Sch. 29312E-Pg.7-9)
(PC-Board 472-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
F101	Fuse, Slo-Blo, 1/8A	A-7	33/B3	L-F	313.125	FU-20

"300" Series (Sch. 29312E-Pg.7-9)
(PC-Board 451-Pg.7-12)

F301	2A, 250V, 3AG, Quick	H-5	12/C3	L-F	312002	FU-13

CONNECTORS (J)
"1000" Series (Sch. 29312E-Pg.7-9)
(PC-Board 472-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
J1001	Receptacle, BNC	E-3	35/F1	AMP	31-2221	CS-249
J1002	NOT USED					
J1003	Display Connector Socket	K-6	37/F2	A-P	929853-06	CS-356-6
J1004	Connector Housing	E-5	9/D5	MOL	2139-8	CS-287-8
J1005	Connector Housing	A-8	-----	MOL	2139-3	CS-287-3
J1006	Contact	H-3	40/A5	K-I	SPECIAL	29316A
J1007	Display Connector Housing	K-7	41/F5	A-P	929853-03	CS-356-3

CONNECTORS (P)
"1000" Series (Sch. 29312E-Pg.7-9)
(PC-Board 472-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
P1001	NOT USED					
P1002	NOT USED					
P1003	12-Pin Male	K-6	* 7/F3	A-P	929838001-06	CS-355-6
P1004	Receptacle - 8-pin	E-5	38/C3	MOL	A-2391-8A	CS-288-8
P1005	Receptacle 3-pin	A-8	39/B5	MOL	A-2391-3A	CS-288-3
P1006	NOT USED					
P1007	6-Pin Male	K-7	*8/B3	A-P	929838-01-03	CS-355-3
P1008	Line Cord	A-8	-----	K-I	-----	CO-9

* On PC-Board 473

TRANSISTORS (Q)
"100" Series (Sch. 29312E-Pg.7-9)
(PC-Board 472-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
Q101	NPN, Switch.	K-6	43/E2	MOT	2N3904	TG-47
Q102	N-Chan dFET, Case R-110	F-3	44/D2	INT	ITE4392	TG-77
Q103	N-Chan dFET, Case R-110	E-3	45/D3	INT	ITE4392	TG-77
Q104	Matched Set With R115 & R116.	F-4	46/D3	K-1	SPECIAL	29427A

"300" Series (Sch. 29312E-Pg.7-9)
(PC-Board 451-Pg.7-12)

Q301	Thyristor, SCR.	E-6	38/C4	MOT	106F1	TG-132
Q302	NPN, Switch.	E-6	31/C3	MOT	2N3904	TG-47
Q303	NPN, Switch	G-6	35/D4	K-1	-----	TG-53
Q304	NPN, Switch	G-6	33/E4	MOT	2N3904	TG-47
Q305	NPN, Switch	G-7	32/E4	MOT	2N3904	TG-47
Q306	PNP, Silicon, TO-92 Case.	G-7	34/E4	K-1	-----	TG-53
Q307	NPN, Switch	G-6	37/E3	MOT	2N3725	TG-131
Q308	NPN, Switch	G-7	36/E3	MOT	2N3725	TG-131
Q309	PNP, Silicon.	F-5	50/D3	MOT	MPS-WA5	TG-133
Q310	PNP, Silicon, TO-92 Case.	G-5	51/D3	K-1	-----	TG-53

RESISTORS (R)
"100" Series (Sch. 29312E-Pg.7-9)
(PC-Board 472-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R101	25KΩ, 75W, Cermet Var	F-3	48/F1	BEC	89P	RP-89-25K
R102	200KΩ, Cermet Trimmer	J-2	49/C2	BEC	72PMR	RP-97-200
R103	100KΩ, 10%, 1/4W, Comp.	J-3	50/D2	MEP	CR25, 5%	R-76-100K
R104	17.4KΩ, 1%, 1/8W, MtF	K-2	51/C2	IRC	CEA-TO-17.4K	R-88-17.4K
R105	768KΩ, 1%, 1/8W, MtF.	J-2	52/C2	IRC	CEA-TO-768	R-88-768
R106	1.1KΩ, 1%, 1/8W, MtF.	J-2	53/C2	IRC	CEA-to-1.1K	R-88-1.1K
R107	11KΩ, 1%, 1/2W, MtF	F-3	54/E2	DLE	MFF	R-169-1K
R108	22M, 10%, 1/4W, Comp.	D-4	55/C3	MEP	CR25, 5%	R-76-22M
R109	100KΩ, 10%, 1/4W, Comp.	L-1	56/D3	MEP	CR25, 5%	R-76-100K
R110	1MΩ, 1%, 1/2W, MtF.	E-3	57/D3	MEP	MF-6C	R-94-1M
R111	47KΩ, 10%, 1/4W, Comp	D-4	58/C3	MEP	CR25, 5%	R-76-47K
R112	33KΩ, 10%, 1/4W, Comp	M-2	59/D3	MEP	CR25, 5%	R-76-33K
R113	9.91KΩ, 1%, 1/2W, MtF	F-2	60/E3	DLE	MFF	R-169-9.91K
R114	270KΩ, 10%, 1/4W, Comp.	M-3	61/D3	MEP	CR25, 5%	R-76-270K
R115	Matched Set with Q104	F-4	62/D3	IRC	CEA-TO-(SEL)	R-88-(SEL)
R116	Matched Set with Q104	F-4	63/D3	IRC	CEA-TO-(SEL)	R-88-(SEL)
R117	1.01M, .1%, 1/2W, MtF	F-2	64/E3	DLE	MFF	R-169-1.01M
R118	1KΩ, ±1%, 1/2W, MtF	G-3	65/D4	MEP	MF-6C	R-94-1K
R119	99M, .1%, 1/2W, MtF	F-1	66/E4	DLE	MFF	R-269-99M
R120	90.9KΩ, 1%, 1/8W, MtF	G-2	67/E4	IRC	CEA-TO-90.9	R-88-90.9
R121	10KΩ, 0.5W, POT	H-1	68/D4	BEC	72PMR-10	RP-97-10
R122	899KΩ, 1%, 1/2W, MtF.	H-1	69/D4	DLE	MFF	R-169-899
R123	95.4KΩ, 1%, 1/2W, MtF	H-2	70/D4	DLE	MFF	R-169-95.4
R124	2M, 0.5W, POT	F-1	71/E4	BEC	72PMR-2M	RP-97-2M
R125	2M, 10%, 1/4W, Comp	J-6	72/F5	MEP	CR25, 5%	R-76-120

"200" Series (Sch. 29312E-Pg.7-9)
(PC-Board 473-Pg.7-11)

R201	120Ω, 10%, 1/4W, Comp	K-7	9/B3	A-B	CB-101-10%	R-76-120
R202	Thick Film.	M-7	10/E3	DLE	LDP14-01-470G	TF-64

RESISTORS (R) (CON'T)
"300" Series (Sch. 29312E-Pg.7-9)
(PC-Board 451-Pg.7-12)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R301	20KΩ, 0.5W, POT	F-6	25/C3	BEC	72PMR-20K	RP-97-20K
R302	330Ω, 10%, 1/4W, Comp	F-6	20/C3	MEP	CR25, 5%	R-76-330
R303	1KΩ, 10%, 1/4W, Comp.	F-6	21/D4	MEP	CR25, 5%	R-76-1K
R304	3.9KΩ, 20%, 3W, WW.	E-6	24/D4	TEP	TS3	R-268-3.9
R305	4.7KΩ, 10%, 1/4W, Comp.	F-7	23/D3	MEP	CR25, 5%	R-76-4.7K
R306	33KΩ, 10%, 1/4W, Comp	E-7	22/C3	A-B	CB-332-10%	R-76-3.3K
R307	82KΩ, 10%, 1/4W, Comp	G-7	19/E3	MEP	CR25, 5%	R-76-82
R308	82KΩ, 10%, 1/4W, Comp	G-7	18/E3	MEP	CR25, 5%	R-76-82
R309	10Ω, 10%, 1/4W, Comp.	E-8	17/F4	A-B	CB-100-10%	R-76-10
R310	10Ω, 10%, 1/4W, Comp.	E-7	16/F4	A-B	CB-100-10%	R-76-10
R311	100KΩ, 10%, 1/4W, Comp.	G-6	44/E3	MEP	CR25, 5%	R-76-100K
R312	100KΩ, 5%, 1/4W, Comp	G-5	45/E3	MEP	CR25, 5%	R-76-100K
R313	6.8MΩ, 5%, 1/4W, Comp	G-5	43/E3	MEP	CR25, 5%	R-76-6.8M
R314	6.8MΩ, 5%, 1/4W, Comp	G-5	46/E3	MEP	CR25, 5%	R-76-6.8M
R315	576KΩ, 1%, 1/8W, Comp	G-5	48/E3	IRC	CEA-T0-576K	R-88-576K
R316	100KΩ, 1%, 1/8W, Comp	G-6	47/E3	IRC	CEA-T0-100K	R-88-100K

SWITCHES (S)
"100" Series (Sch. 29312E-Pg.7-9)
(PC-Board 472-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
S101	Line Battery.	B-6	77/C2	K-I	SPECIAL	SW-397
S102	Pin, Contact.	F-3	79/E2	MOL	SPECIAL	CS-357
S103 (A-H)	Pushbutton Switch	Several	80/F2	K-I	SPECIAL	SW-405
S104	Pin, Contact.	F-2	81/E3	K-I	SPECIAL	CS-357
S105	Switch, Slide, DPDT	A-6	83/B3	C-W	GG350PCDPDT	SW-318
S106	Pin, Contact.	F-2	85/E3	MOL	SPECIAL	CS-357
S107	Pin, Contact.	F-1	86/E4	MOL	SPECIAL	CS-357
S108	Power Switch.	C-8/C-7	88/E5	CLB	SPECIAL	SW-406

TRANSFORMERS (T)
"100" Series (Sch. 29312E-Pg.7-9)
(PC-Board 472-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
T101	Transformer, Power.	A-6	90/B2	K-I	-----	TR-168

"300" Series (Sch. 29312E-Pg.7-9)
(PC-Board 451-Pg.7-12)

T301	Transformer, Power.	H-6	39/F3	K-I	-----	TR-170

INTEGRATED CIRCUITS (U)
"100" Series (Sch. 29312E-Pg.7-9)
(PC-Board 472-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
U101	4-1/2 Digit Logic Processor	L-4	92/D2	INT	7103A	LSI-11-1
U102	4011 CMOS Unbuffered.	K-5/M-6	93/C2	MOT	MC14011CP	IC-102
U103	4-1/2 Digit Analog-Processor.	M-2	94/D2	INT	8052A	LSI-12
U104	Operational-Amp TO-5	F-3	95/D3	F-I	LF356-4	IC-152

INTEGRATED CIRCUITS (U) (CON'T)
"200" Series (Sch. 29312E-Pg. 7-9)
(PC-Board 473-Pg.7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
U201	Digit Driver.	K-6	11/C3	T-I	75492	IC-169
U202	Segment Driver.	M-7	12/F3	MOT	4511	IC-168

"300" Series (Sch. 29312E-Pg.7-9)
(PC-Board 451-Pg.7-12)

U301	Dual D-Type Flip-Flop, 14-Pin Dip .	F-7	14/D3	RCA	CD4013AE	IC-103
U302	1.1V Micro-Power Detector	G-6	49/E3	INT	ICL8211CPA	IC-177

VOLTAGE REGULATORS (VR)
"100" Series (Sch. 29312E-Pg.7-9)
(PC-Board 472-Pg.7-10)

Circuti Desig.	Description	Sch. Location	PC-Board ITem No./ Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
VR101	Diode, Zener.	G-4	97/D4	MOT	1N751	DZ-59
VR102	Diode, Zener.	G-4	98/D4	MOT	1N751	DZ-59
VR103	+5V, 3-Term, TO-220	D-6	99/B4	MOT	MC7805CT	IC-93
VR104	+15V, 3-Term, LO-Power.	C-7	100/C5	MOT	MC78L15CP	IC-170
VR105	-15V, 3-Term.	D-8	101/B5	MOT	MC7915CT	IC-174

"300" Series (Sch. 29312E-Pg.7-9)
(PC-Board 451-Pg.7-12)

VR301	8.2Volt, Zener.	F-6	10/C3	MOT	1N765A	DZ-61

CRYSTAL (Y)
"100" Series (Sch. 29312E-Pg.7-9)
(PC-Board 472-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Item No./ Location	MFr. Code	Mfr. Desig.	Keithley Part No.
Y101	Quartz, ±0.01%, 100kHz.	E-4	103/C3	NEL	NE34PE	CR-8

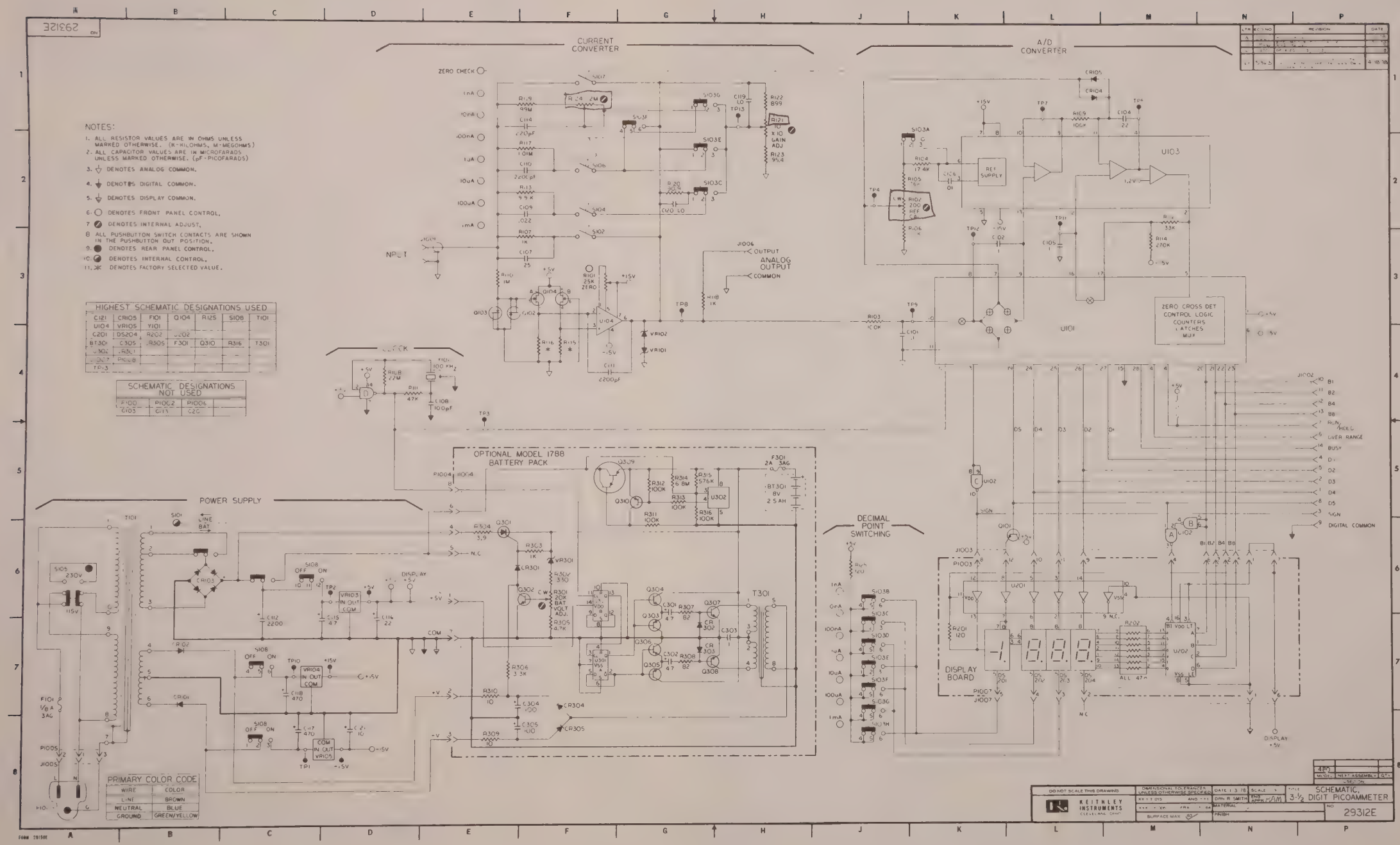
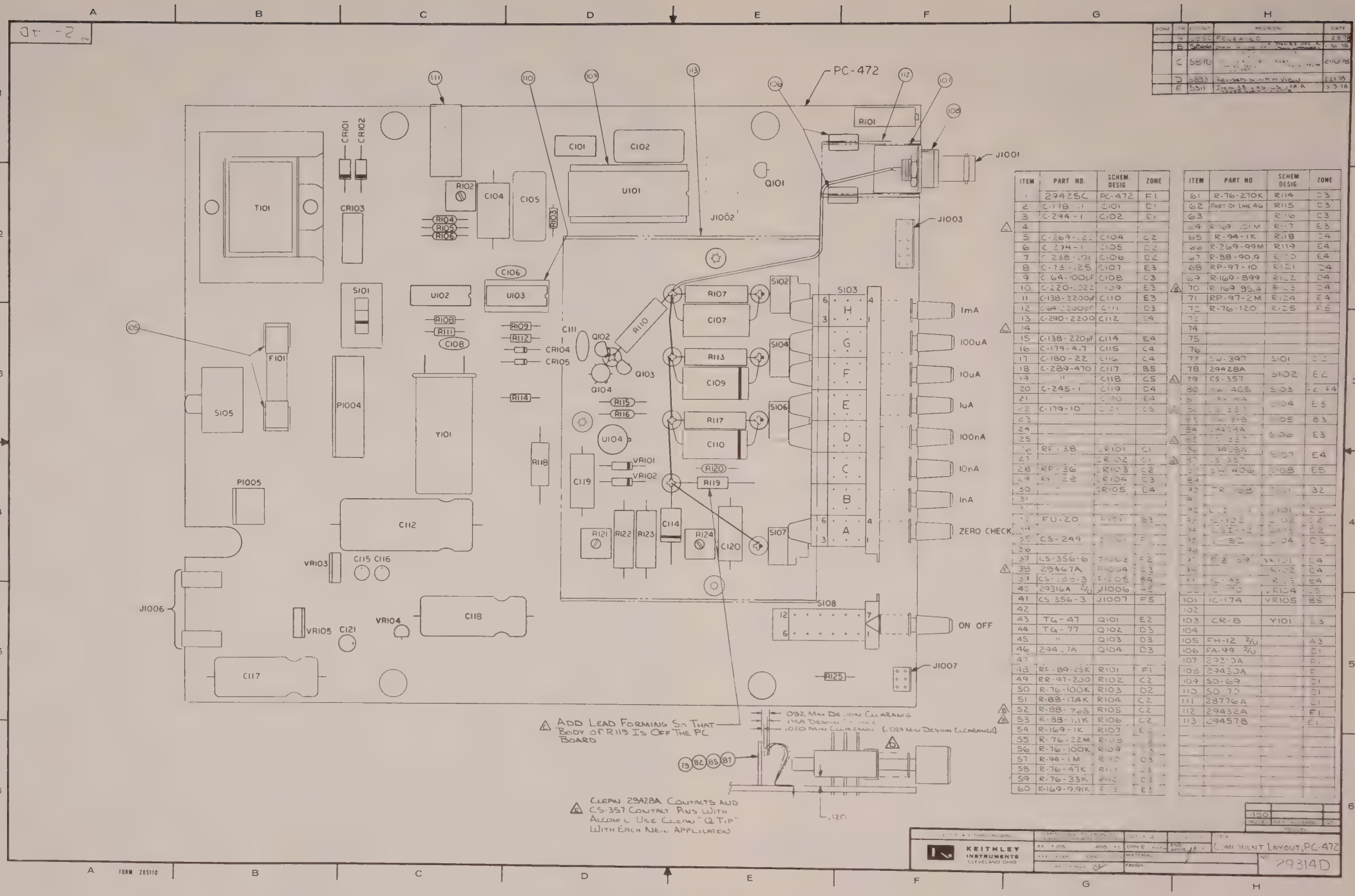

CURRENT CONVERTER
A/D CONVERTER
POWER SUPPLY
CLOCK
OPTIONAL MODEL 1788 BATTERY PACK
DECIMAL POINT SWITCHING
DISPLAY BOARD
ZERO CROSS DET CONTROL LOGIC COUNTERS LATCHES MUX
NOTES:
1. ALL RESISTOR VALUES ARE IN OHMS UNLESS MARKED OTHERWISE. (K-KILOHMS, M-MEGOHMS)
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS MARKED OTHERWISE. (pF-PICOFARADS)
3. DENOTES ANALOG COMMON.
4. DENOTES DIGITAL COMMON.
5. DENOTES DISPLAY COMMON.
6. DENOTES FRONT PANEL CONTROL.
7. DENOTES INTERNAL ADJUST.
8. ALL PUSHBUTTON SWITCH CONTACTS ARE SHOWN IN THE PUSHBUTTON OUT POSITION.
9. DENOTES REAR PANEL CONTROL.
10. DENOTES INTERNAL CONTROL.
11. DENOTES FACTORY SELECTED VALUE.
HIGHEST SCHEMATIC DESIGNATIONS USED
SCHEMATIC DESIGNATIONS NOT USED
PRIMARY COLOR CODE
WIRE / COLOR
LINE / BROWN
NEUTRAL / BLUE
GROUND / GREEN/YELLOW
KEITHLEY INSTRUMENTS CLEVELAND, OHIO
SCHEMATIC, 3-1/2 DIGIT PICOAMMETER
NO. 29312E

FIGURE 7-2. Model 480 3-1/2 Digit Picoammeter: Schematic No. 29312E


PC-472
T101
F101
S101
S105
P1004
Y101
P1005
J1006
C112
C117
VR103
C115 C116
VR105 C121
VR104
C118
CR101 CR102
CR103
R102
C104
C105
R103
R104
R105
R106
C101
C102
U101
Q101
J1002
R101
J1001
J1003
U102
U103
C106
R108
R111
C108
R109
R112
CR104
CR105
R114
C111
Q102
R110
Q103
Q104
R115
R116
U104
VR101
VR102
R118
C119
R120
R119
C107
C109
C110
R107
R113
R117
S102
S103
S104
S106
S107
S108
H
G
F
E
D
C
B
A
1mA
100uA
10uA
1uA
100nA
10nA
1nA
ZERO CHECK
ON OFF
R121
R122
R123
C114
R124
C120
R125
J1007
C113
R126
C122
R127
C123
R128
C124
R129
C125
R130
C126
R131
C127
R132
C128
R133
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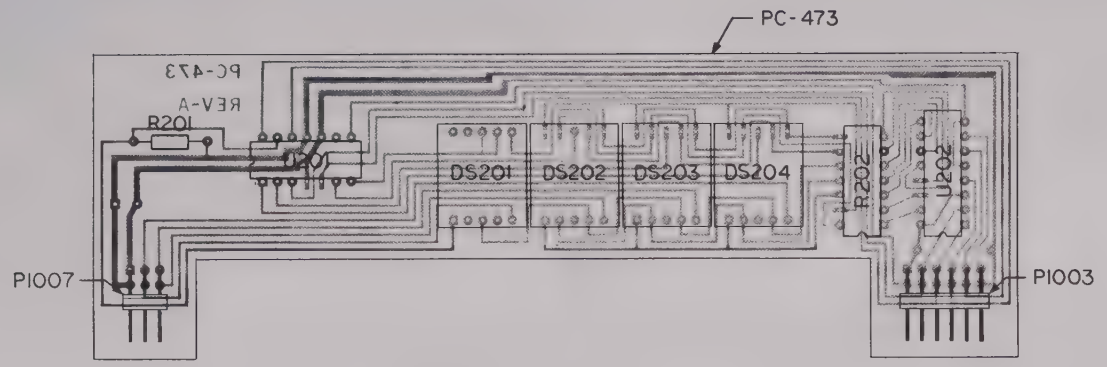
R145
C141



ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	29183C	PC-472	E2
2	Not Used		
3	DD-17	DS201	D3
4	DD-16	DS202	D3
5	"	DS203	D3
6	"	DS204	E3
7	CS-355-6	P1003	F3
8	CS-355-3	P1007	B3
9	R-76-120	R201	B3
10	TF-64	R202	E3
11	IC-169	U201	C3
12	IC-168	U202	F3

ZONE	LTR	ECO NO.	REVISION	DATE
	A	5852	RELEASED	1-23-78
	B	5870	DELETED C201	2 10 16

480 — MODEL | NEXT ASSEMBLY | QTY USED ON

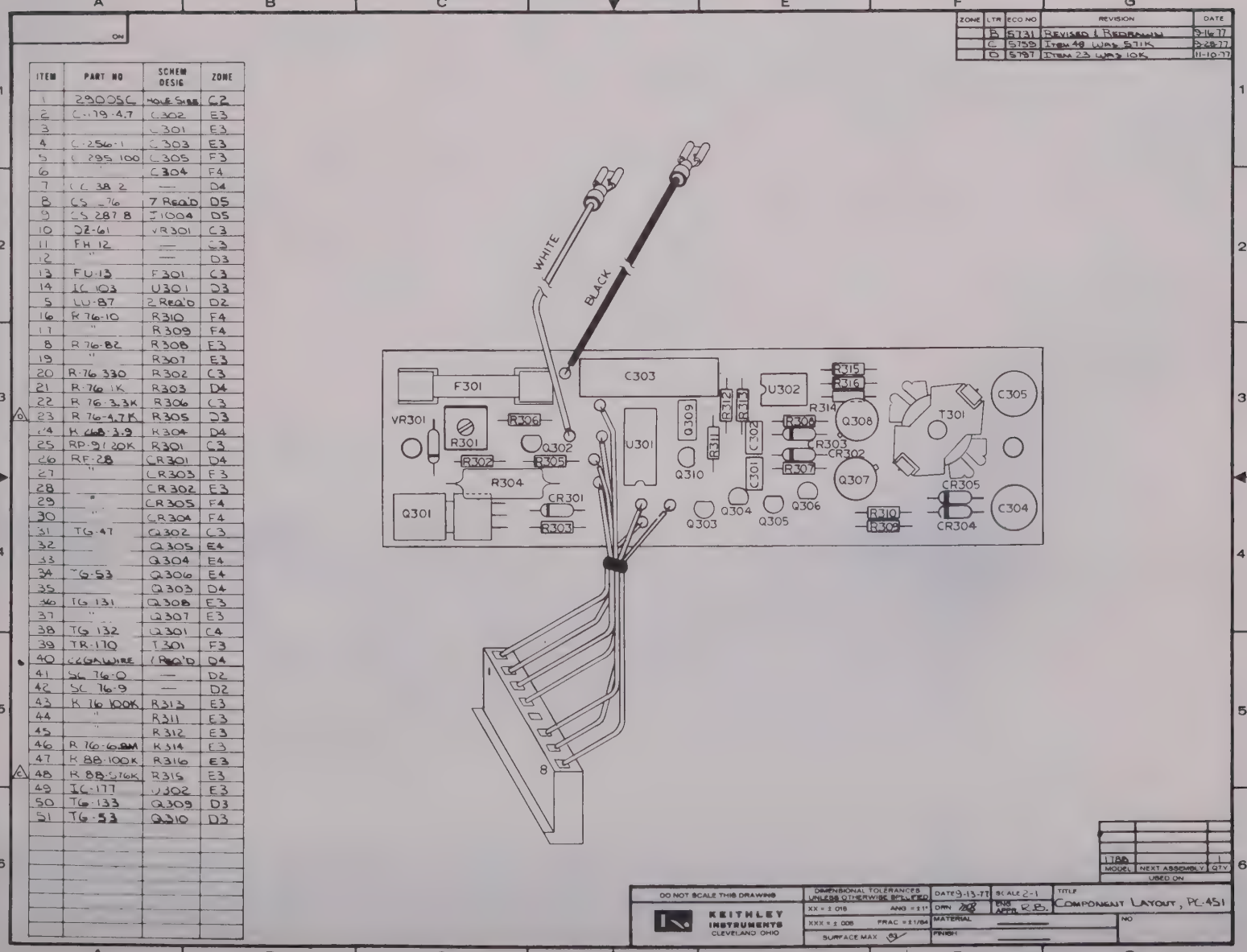
DO NOT SCALE THIS DRAWING — DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX = ± .015, ANG = ±1, XXX = ± .005, FRAC ±1/64, SURFACE MAX 63 — DATE 1-3-78 — SCALE 2-1 — DRN R SMITH — ENG APPR — MATERIAL — FINISH

KEITHLEY INSTRUMENTS CLEVELAND OHIO

TITLE: COMPONENT LAYOUT, PC-473

NO 29315C

FIGURE 7-4. Component Layout, PC-473



ITEM	PART NO	SCHEM DESIG	ZONE
1	29005C	HOLE SHIELD	C2
2	C-179-4.7	C302	E3
3		C301	E3
4	C-256-1	C303	E3
5	C 295 100	C305	F3
6	"	C304	F4
7	CC 38 2	—	D4
8	CS -76	7 REQ'D	D5
9	CS 287 8	J1004	D5
10	D2-61	VR301	C3
11	FH 12	—	C3
12	"	—	D3
13	FU-13	F301	C3
14	IC 103	U301	D3
15	LU-87	2 REQ'D	D2
16	R 76-10	R310	F4
17	"	R309	F4
18	R 76-82	R308	E3
19	"	R307	E3
20	R-76 330	R302	C3
21	R-76 1K	R303	D4
22	R 76-3.3K	R306	C3
23	R 76-4.7K	R305	D3
24	R 76-3.9	R304	D4
25	RP-91 20K	R301	C3
26	RF-28	CR301	D4
27	"	CR303	F3
28		CR302	E3
29	"	CR305	F4
30	"	CR304	F4
31	TG-47	Q302	C3
32		Q305	E4
33		Q304	E4
34	TG-53	Q306	E4
35		Q303	D4
36	TG 131	Q308	E3
37	"	Q307	E3
38	TG 132	Q301	C4
39	TR-170	T301	F3
40	22GA WIRE	1 REQ'D	D4
41	SC 76-0	—	D2
42	SC 76-9	—	D2
43	R 76 100K	R313	E3
44	"	R311	E3
45	"	R312	E3
46	R 76-6.8M	R314	E3
47	R 88-100K	R316	E3
48	R 88-576K	R315	E3
49	IC-177	U302	E3
50	TG-133	Q309	D3
51	TG-53	Q310	D3

ZONE	LTR	ECO NO	REVISION	DATE
	B	5731	REVISED PER DRAWING	9-16-77
	C	5759	ITEM 48 WAS 511K	9-28-77
	D	5787	ITEM 23 WAS 10K	11-10-77

DO NOT SCALE THIS DRAWING

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED: XX = ± .018, ANG = ± 1°, XXX = ± .005, FRAC = ± 1/64, SURFACE MAX 63

KEITHLEY INSTRUMENTS CLEVELAND OHIO

DATE 9-13-77 DRN DES APPR K.B.

SCALE 2-1

TITLE COMPONENT LAYOUT, PC-451

MATERIAL

FINISH

NO

LTR | MODEL | NEXT ASSEMBLY | QTY | USED ON

FIGURE 7-5. Component Layout, PC-451, Battery Pack Board.

KEITHLEY INSTRUMENTS, INC.
28775 AURORA ROAD
CLEVELAND, OHIO 44139

SERVICE FORM

MODEL NO._____ SERIAL NO._____ P.O. NO._____ DATE_____ R-

NAME _____ PHONE _____

COMPANY _____

ADDRESS _____ CITY _____ STATE _____ ZIP_____

1. Describe problem and symptoms using quantitative data whenever possible (enclose readings, chart recordings, etc.) _____

_____

_____ (Attach additional sheets as necessary).

2. Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

3. List the positions of all controls and switches on both front and rear panels of the instrument. _____

_____

4. Describe input signal source levels, frequencies, etc. _____

_____

_____

5. List and describe all cables used in the experiment (length, shielding, etc.).

_____

_____

6. List and describe all other equipment used in the experiment. Give control settings for each. _____

_____

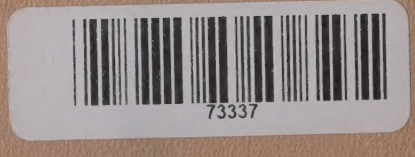
_____

7. Environment:
   Where is the measurement being performed? (Factory, controlled laboratory, out-of-doors, etc.) _____
   What power line voltage is used? _____ Variation? _____ Frequency? _____
   Ambient temperature? _____°F. Variation? _____°F. Rel. Humidity? _____
   Other _____

8. Additional Information. (If special modifications have been made by the user, please describe below.) _____

_____

_____ REV 0774



Keithley Instruments, Inc./28775 Aurora Road/Cleveland, Ohio 44139/(216) 248-0400/Telex: 98-5469
Keithley Instruments GmbH/Heiglhofstrasse 5/D-8000 München 70/(089) 714-40-65/Telex: 521 21 60
Keithley Instruments, Ltd./1, Boulton Road/GB-Reading, Berkshire RG2 ONL/(0734) 86 12 87
Keithley Instruments SARL/44, Rue Anatole France/F-91121 Palaiseau Cedex/01-014-22-06/Telex: (842) 204188